Report: Field Data Collection Summary Report for the Sabine-Neches Waterway Study

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MEMORANDUM FOR RECORD

SUBJECT: Field Data Collection Summary Report for the Sabine/Neches Waterway Study

Introduction

1. In response to a request of the U.S. Army Engineer District, Galveston (SWG), the U. S. Army Engineer Research Development Center - Waterways Experiment Station (ERDC-WES) discussed plans with the District for the data collection in the Sabine-Neches Waterway. Mr. Ed Reindl and Ms Lynn Robinson requested that the Measurement and Analysis Group of ERDC-WES provide personnel and equipment to investigate the hydrodynamics, bathymetry and salinity concentrations in the area of the Sabine River, Neches River, Gulf Intercoastal Waterway (GIWW), Sabine Lake, and the Sabine Pass areas of the waterway. It was requested that WES provide support for and complete this effort prior to 30 June 2002.

2. The purpose of the data collection was to provide detailed tidal hydrodynamic and salinity information that can be used to address concerns of channel deepening in the Sabine Neches Waterway and the effect it creates in the study area. The data collected will also be used to verify numerical model simulations of the salinity movement in the project area.

3. The data collection program was planned and performed by the Measurement and Analysis Group of the Estuarine Engineering Branch, Coastal and Hydraulics Laboratory (CHL), ERDC-WES. The equipment provided by ERDC-WES included an Acoustic Doppler Current Profiler (ADCP), Acoustic Doppler Velocity Meters, pressure measurement tide gauges, salinity concentration sensors, water sampling pumps and a meteorological station. A Contractor performed the elevation survey of the instrument locations within the study area.

FIELD DATA COLLECTION

Long-term Instrumentation

4. Sixteen long-term data collection locations within the study area were established to provide adequate coverage for determination of tidal velocity magnitudes and directions, ranges of water-level elevations, and changes in salinity concentration. At each of these data collection locations, instruments were installed for the purpose of collecting combinations of the above listed parameters over an eight-month period. The instrument deployment locations within the study area are shown in Figures 1-4. With authorized permission from the United States Coast Guard (USCG), existing Aids-to-Navigation (ATON) structures were used whenever possible as platforms for the deployment of the instruments. Some typical examples of these deployments are shown in Figures 5-9. In some deployment areas, no ATON structures were available and other methods for deployment of the instruments were utilized. Figures 10 and 11 illustrate some of the typical methods used for deploying the instruments.

5. The data collection program was initiated with instruments being installed in May 2001. At all data collection locations (Stations 1-16), a pressure sensing water level recorder and salinity recorder were installed. The water level recorders were *Water*LOG® DH-21 submersible pressure transducer and data logger. This instrument has unique dry air system that provides automatic compensation for changes in atmospheric pressure. The instrument is fully programmable to set the sampling rate, starting time, and output units. The accuracy of the pressure sensor is ± 0.01 feet.

6. The salinity recorders used in the data collection effort were YSI 6000 R® Water Quality Probes (See Figure 12). This instrument provides the capability of measuring insitu temperature, conductivity and salinity during long-term unattended monitoring applications. The instruments are fully programmable for selecting the sampling interval. Calibration is accomplished simply by immersing

the sensor in a standard salinity solution of known concentration, waiting for stable readings to appear, and setting the instrument to the new calibration value.

7. A meteorological station was installed on the rooftop (5 meters above the ground) of one of the classrooms buildings on the campus of Lamar University near Station 2. The station recorded wind speed, wind direction, ambient air temperature and barometric pressures. These meteorological parameters were monitored in 15-minute increments for the duration of the data collection program. The meteorological station was a Campbell Scientific W2000® programmable weather data acquisition station similar to that shown in Figure 13. The data collection platform is typically located at some central location in the study area and mounted approximately 5 meters above the ground or water. The data acquisition system is a battery-powered microcomputer with a real-time clock, a serial data interface, and programmable analog-to-digital converter. The battery is constantly charged using a solar panel charging system located near the system. Various programming options are available for setting the sampling interval of the system for the input signals from the wind speed and direction sensors. The system can be programmed to sample the input signals each second over a set period of time to determine the mean wind speed, mean direction, maximum wind gust speed, and maximum wind gust direction. The data are processed internally and stored in formats specified in a user-entered output table. The accuracy of the analog input of the wind speed and directions sensors is ± 1.0 mile per hour (mph) and ± 3.0 degrees, respectively. The barometric pressure sensor, model CS105, has an accuracy of ± 0.5 millibars (mb) over a range from 600 – 1060 mb. No rain gage was employed during the study period.

8. At nine of the data collection locations (Stations 3, 4, 7, 9, 10, 11, 12, 13, and 14), Acoustic Doppler Velocity (ADV) meters were installed in addition to the water level and salinity recorders. These velocity meters were used to determine the tidal flow magnitudes and directions in the areas of the waterway in which they

were installed. The ADV's used were Nortek Aquadopp® current meters, see Figure 14. A typical deployment for these instruments is depicted in Figure 15. These ADV instruments are programmable current meters that allow for measurements with time scales ranging from 1 second to 1 year. The current meter has no moving parts, requires no recalibration, and uses proven Doppler technology to provide 3-dimensional vector velocity measurements. This type of velocity sensor includes a built-in solid-state recorder, pressure sensor, compass and tilt sensor, batteries and an internal temperature sensor. The pressure sensor is a silicone piezo-resistive pressure sensor that has an accuracy of ± 0.003 feet.

Elevation Survey

9. An elevation survey was performed to determine the existing elevations of the long-term instruments deployed in the project study area. These instrument elevations were provided to the numerical modelers for use in the development of the model.

Field Procedures At Installation and During the Monitoring Program

10. The water level recorders were differential pressure sensor devices that record the depth of water over the sensor. Figures 5 -11 illustrate the typical deployment methods that were used. The recorded pressures are atmospherically corrected using a dry air system in the electronics cable that extends above the water surface to the data recorder housing. The pressure sensors were deployed at a depth well below the predicted low tide level for the data collection period and were programmed to record the water level readings at 15-minute intervals. Instrument service periods were performed a minimum of every 3 weeks. During these service periods, specific procedures were routinely followed prior to retrieving each water level sensor and immediately following redeployment of the sensor. Immediately before and following the servicing of the water level sensors, a physical measurement of the depth of submergence was obtained and recorded for verification of the depth readings logged by the sensor. These procedures were implemented and followed for data quality assurance purposes. In addition, prior

to the beginning of the deployment period each sensor was re-zeroed at the existing atmospheric pressure. If the instrument pressure could not be reset to zero before deployment then the instrument was pulled from service.

11. The salinity recording sensors were deployed at or near the level of the water level sensor also as shown in Figures 5-11. The sensors were set-up to record salinity concentrations and temperatures at 15-minute intervals. Depth recording capabilities were available with these instruments and were recorded. The recorded depths required correction for atmospheric pressure changes in the area. These depth recordings were available for use in the event that the designated water-level recorder malfunctioned or was damaged. Specific procedures were routinely followed prior to retrieving and immediately following redeployment of the each salinity sensor. Immediately before and after the salinity sensors were serviced, a physical measurement of the depth of submergence was obtained and recorded for verification of the depth readings logged by the sensor. A water sample was also obtained at the depth of the salinity sensor. These water samples were returned to ERDC-WES and analyzed in the laboratory for salinity concentration. The salinity concentration values from the laboratory analysis would later be used in the data processing efforts to indicate salinity-reading offsets at the end of each deployment period. Prior to cleaning the sensor, it was immersed in a standard salinity solution of known concentration, in parts per thousand (ppt), to determine the offset in the sensors reading due to aquatic fouling. An example of the biological growth that can accumulate on the instruments is shown in Figure 16. The sensor readings in the salinity standard were allowed to stabilize for temperature compensation and the value of the salinity reading recorded. After the instrument was cleaned of any dirt and aquatic growth it was again immersed in the standard salinity solution, readings allowed to stabilize and the sensor reading recorded. This procedure was performed for field calibration of the sensor. The procedures described above were followed for data quality assurance purposes. If the instrument salinity

reading could not be reset to match the calibration standard value before deployment then the instrument was pulled from service.

12. Service trips to download data, clean and recalibrate instruments were performed in 3-week intervals. All work performed during the service trips on the instruments were recorded in a field-log book. These field records provided a quality control and assurance check for each of the instruments used in the project study effort.

Intensive Velocity and Salinity Data Collection

13. In addition to the long-term data collection effort, an intensive velocity data collection effort was performed using a boat mounted ADCP to obtain detailed hydrodynamic information over a single spring tide event. A total of 10 velocity transects (Figures 17-20) were monitored during a 25-hour period. Immediately following each ADCP data collection transect, water samples were obtained at predetermined locations and depths for identification of salinity concentration changes with tidal flows.

14. Acoustic equipment such as the ADCP is used for fast and accurate profiling in the field of velocity magnitude and direction. The equipment employed for this investigation was 1200 kHz frequency RD Instruments Broad-Band ADCP. The instrument was mounted over the side of the boat with the acoustic transducers submerged and data were collected while the vessel was underway.

15. A general description of the ADCP operation is provided here. The acoustic transducers of the ADCP transmit sound bursts into the water column. These sound bursts are then scattered back to the instrument by particulate matter suspended in the flowing water. The ADCP transducers listen for the returning signal and assign depth and velocity to the received signal based on the time of travel and the change in frequency caused by the moving particles, respectively. The change in frequency is referred to as a Doppler shift. The ADCP is also

capable of measuring vessel direction, velocity magnitude and direction, water temperature, and bottom depth. Communication with the instrument for setup and data recording is performed with a portable computer using manufacturer-supplied software, hardware, and communication cable. The ADCP is for deployment on the side of a vessel that is operated at a very slow speed (less than 2.5 knots).

16. The general location of the ADCP transects for the intensive velocity data collection effort are shown in Figures 17-20 and are described below. Transect R1 was located south of Mesquite Point at Channel Marker "36" in the Sabine Pass Channel. Transect R2 was located was located directly to the southwest of Mesquite Point in the Port Arthur Canal Channel. Transect R3 was located near channel marker "48" of the Port Arthur Canal Channel. Transect R4 extended the across the GIWW just west of the Texas State Highway No. 87 bridge. Transect R5 was located at channel marker "50" in the Sabine-Neches Canal just above the intersection with the GIWW. Transects R6 was located just east of the Rainbow Bridge (Texas State Highway No. 87) in the Neches River at channel marker "8". Transect R7 was located just north of the junction of the Neches River and Sabine-Neches Canal near Stewts Island. Transect R8 was located at the front range marker of Range "O" on the Sabine River. Transect R9 and R10 were located at mile markers 260 and 255 of the GIWW east, respectively. The near shore areas of these transects along both sides of the channel were found to be very shallow and therefore data collection at these transects were limited to the deeper water of the navigable channel as identified by the navigation markers for the channel.

Data Presentation

Water Level.

17. As previously discussed, sixteen locations were established in the study area for obtaining long-term records of water level (tide) changes and salinity concentrations. The long-term data collection period extended from 16 May 2001 until 10 January 2002. The majority of the instruments performed satisfactorily during the 8-month deployment period. A time history log of each water level instrument during the deployment period is provided in Table 1. However during the long-term deployment, two of the water-level recorders (Station 2 and Station 7) were destroyed after the mounting unit were pulled or knocked from the piling and the instrument was either totally lost or became submerged. The water-level recorder from Station 2 was recovered from the USCG in Galveston after they recovered it and replaced the damaged ATON to which the recorder was mounted. However, the water-level recorder from Station 7 was never located after it was knocked from the range marker platform. The water-level recorder housings are water-resistant but are not waterproof. When the unit is submerged, the recorder housing becomes filled with water and shorts out all the electronics. As a result, no data could be retrieved from the instruments once this occurred. Due to the project economic constraints, no replacement instruments were available for replacement of the damaged or lost instruments to continue the recording of water level measurements at these locations. One water-level recorder was the unfortunate victim of a natural disaster, a flood event that occurred in early June 2001 of the deployment period. The water-level recorder for Station 1 (Upper Beaumont), located in the Neches River near Pine Island Bayou, was destroyed by a major flood. The water level rose to a level that caused the recorder housing to become submerged and causing the electronics to fail due to water entering the housing. No data could be recovered from this instrument. No replacement instrument was available to continue recording of water level at this location. Figures 21 - 35 are the time history plots of the water-level changes in Sabine/Neches Waterway River Project study area.

Salinity

18. As previously discussed, 16 locations were established in the study area for obtaining long-term records of salinity concentrations. A time history log of each salinity recording instrument operation during the deployment period is provided in Table 1. Time history plots of salinity data collected during the deployment period 16 May, 2001 through 10 January, 2002, are shown in Figures 36 - 52. The observed maximum salinities for each data collection location are quite varied depending on the instrument location. At least four significant freshwater inflow events occurred during the data collection period, which are evident in the salinity time history as a reduction in the salinity concentrations. These events occurred around the periods 06/15/01, 07/10/01, 09/03/01 and 10/03/01. The freshwater event that occurred around 09/03/01 resulted in significant decreases in the salinity concentrations at all salinity sensor locations including the sensors located in Sabine Lake and at Sabine Pass. Salinity concentrations recorded at Station 7, located near Sabine Pass, were consistently higher, as shown in Figure 44, than those recorded at the other locations due to the proximity of the instrument location near the Gulf of Mexico.

19. Biological fouling of the salinity sensors is usually more prevalent in the higher salinity concentration areas, during the spring and summer months, when the water temperature in the shallow areas increased. The effect of biological growth on the salinity sensor is to alter the calibration of the conductivity electrodes. The result of this biological fouling is a pronounced drift ± from the initial reading when the instrument was redeployed after servicing. The time interval between service trips was rarely longer than 3 weeks. The regularity of the intervals to clean the sensors and download the data proved to be very effective in minimizing the effects of biological fouling of the salinity sensors. This is evident in the comparison of the water sample salinity concentrations to the sensor readings prior to retrieval and immediately following deployment of the sensor at the time of the service trip.

20. As stated earlier, water samples were also collected at a minimum of three depths at the centerline of each ADCP transect. Samples were pumped from a predetermined depth into 100-ml plastic bottles for storage and transport. These samples were transported to WES for analysis following the completion of the field effort. These samples were later analyzed in the laboratory to identify changes in salinity during various periods of the ebb and flood tide. The results of the laboratory salinity analysis are shown in Table 2-8 and are plotted in Figures 53-60. The salinity concentrations shown in these Figures illustrate a vertical stratification of salinity in the water column at all transects except Transect 10 in the GIWW east. The salinity variations between surface and bottom depths within the study area were on the average 10 ppt over the 25-hour data collection period. The highest salinity concentrations occurred at the bottom depths of Transects 1 and 3

Meteorological Data

21. The data from the meteorological data acquisition system were processed to provide the time history plots of the various parameters. Figures 61-64 are the plots of the recorded wind direction, wind speed, air temperature, and the atmospheric pressure during the 6-month data collection effort. In addition, other meteorological data were obtained from an existing National Oceanographic and Aerospace Administration (NOAA) located in Sabine Texas. This NOAA meteorological location is identified as Station SRST2 - Sabine, TX. It is owned and maintained by the National Data Buoy Center and is located at coordinates 29.67 N 94.05 W. The recorded data from this location includes wind speed, wind direction, wind gusts, atmospheric pressure and air temperature. The data is available and can be downloaded at the website http://seaboard.ndbc.noaa.gov.

Velocity Data

22. As stated previously, a single ADV or multiple depth ADV's were deployed at eight stations in the study area, see Table 1. Meters at Stations 3, 4, 6, and 13 were continuously being moved due to passing vessels. A warning buoy was deployed toward the channel side of the instrument deployment to deter ships from the location of the deployment. However, this did not deter the passing ships and eventually at Station 4, the buoy and current meters were completely destroyed. Several unsuccessful attempts were made to deploy drag-hooks and lines to locate the missing meters and deployment pod. Two other instrument deployment sites were plagued with problems during the data collection period. The instrument pod and buoy deployed at Station 6 were continually being moved by the passing navigation traffic. During the September 2001 service trip, upon retrieval of the instruments, the cables and sensors had become so tangled that the velocity meters and current meters were removed from the deployment. This was done to prevent the installation from being damaged beyond repair or lost. Station 13 in the western GIWW channel was also the victim of several passing towboats during the long-term deployment. The data are presented in Figures 65-78. The most significant velocity magnitudes were generally located at Station 7. The highest velocities recorded at this location were 3.1 and 3.2 fps for ebb and flood flow, respectively. The maximum velocities recorded at the other locations ranged from 0.8 fps to 2.6 fps.

Equipment Deployment Locations and Sensor Elevations

23. At the completion of the long-term data collection, a survey crew was employed to obtain the elevation datums of the reference points marked at each depth measuring sensor. These reference points were established at the time the sensors were installed and provided an established measurement point which was used for the calibration monitoring of the depth measuring sensors. The North American Vertical Datum of 1988 (NAVD88) was the elevation datum referenced at each of the sensor locations. Table 9 provides a listing of the instrument location in latitude and longitude, reference point information and the NAVD88

elevation determination of the sensor zero level and the arbritrary datum level used in the time history plots of the water level (tide) sensors.

24. The field data collection effort was completed on 26 October 2001. The data reduction was completed in December 2001.

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Table 1

Sabine Neches Field Data Instrumentation Log

Station No.	Instrument	May	June	July	August	September	October	November	December	January
1 Upper Beaumont	Tide	XXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX
	Salinity	———	———	———	———	———	———	———	———	———
	Tide Recorder Flooded (05/01); Instrument Destroyed; Data Lost; No Replacement; Salinity Sensor Depth Recording Used for Missing Tide Data									
2 Beaumont	Tide	———	———	XXXXXXXX	XXXXXX	———	———	———	———	———
	Salinity	———	———	XXX	XXXXXX	———	———	———	———	———
	Instrument Piling Damaged by Vessel 07/01;Instruments Recovered from USCG; Tide Level Recorder Destroyed; Data Lost; Replacement Installed; Salinity Sensor and Data Recovered									
3 Rainbow Bridge	Tide	———	———	XX	XXXXXXXX	———	———	———	———	———
	Salinity	———	———	———	———	———	———	———	———	———
	Current		———	———	———	———	———	———	———	———
	Tide Level Recorder Malfunction 07/01; Returned for Service; Reinstalled 08/01 Salinity Sensor Depth Recording Used for Missing Tide Data									
4 Lower Sabine R.	Tide	———	———	———	———	———	XXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX
	Current		———	———	———	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX
	Tide Level Recorder Malfunction; Returned for Service; Current Meter Deployment Lost;Two Separate Recovery Attempts Failed; No Replacements Available									
5 Orange	Tide	———	———	———	———	———	———	———	———	———
	Salinity	———	———	———	———	———	———	———	———	———
	Instrument Deployment Damaged by Flood (05/01); Salinity Sensors Retrieved (07/01); Instrument Deployment Relocated									
6 Port Arthur	Tide	———	XXXX	XXX	———	XXXXXXX	———	———	———	———
	Salinity	———	———	———	———	———	———	———	———	———
	Current		———	———	———	———	X	XXXXXXXX	———	———
	Tide Level Recorder Malfunction (06/01 and 09/01); Problem Corrected; Salinity Sensor Depth Recording Used for Missing Tide data; Instrument Deployment Destroyed 09/01; Salinity Sensor Reinstalled at Tide Recorder Location; Current Meter Removed									
7 Sabine Pass	Tide	———	XX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX
	Salinity	———	XX	XXXX	———	———	———	———	XXXXX	XXXXXXXX
	Current		———	———	———	———	———	———	XXXXXXX	———
	Instrument Deployment Hit By Vessel (06/01); Salinity Sensor and Tide Recorder Lost; Salinity Sensor Replaced 07/01; No Replacement For Tide Level Recorder; Salinity Sensor Depth Recording Used for Tide Recorder									
	XXXXXXX = Sensor not operational and no data available during this period ——— = Sensor operational and recording data during this period									

Table 1(Concluded)

Sabine Neches Field Data Instrumentation Log

Station No.	Instrument	May	June	July	August	September	October	November	December	January
9 Upper Sabine Lake	Tide					XXXXXXX	XXXXXXX	XXXXXXX		
	Salinity									
	Current								XXXXXXX	XXX
10 Lower Sabine Lake	Tide		XXXX	XXX			XXXXX	XXXXXXX	XX XXXXX	
	Salinity									
	Current							XXXXX	XXXXX	
	Tide Level Recorder Malfunction (06/01 and 10/01); Problem Corrected; Salinity Sensor Depth Recording Used for Missing Tide Data									
11 Blacks Bayou	Tide									
	Salinity									
	Current							XXX	XXXXXXX	XXX
12 GIWW East	Tide						XXXXXXX	XXXXXXX	XXXXXXX	XXX
	Salinity									
	Current								XXXXXXX	XXX
	Tide Level Recorder Malfunction; Problem Corrected; Salinity Sensor Depth Recording Used for Missing Tide Data									
13 GIWW West	Tide							XXXXXXX	XXXXXXX	XXX
	Salinity		XXX	XXXXX						
	Current									
	Instrument Deployment Hit By Vessel (06/01); Salinity Sensor and Data Lost;Replacement Installed									
14 Johnsons Bayou	Tide									
	Salinity									
	Current							XXXXXXX	XXXXXXX	XXX
15 Keith Lake	Tide							XXXXXXX	XXXXXXX	
	Salinity							XXXXXXX	XXXXXXX	
16 Willow Bayou	Tide			XXX	XXXX					
	Salinity									
	Tide Level Recorder (07/01) Malfunction; Problem Corrected; Salinity Sensor Malfunction (09/01); Problem Corrected Salinity Sensor Depth Recording Used for Missing Tide Data									

XXXXXXX = Sensor not operational and no data available during this period

= Sensor operational and recording data during this period

Table 2
Transect R1 Salinity During 25-hr Survey

Range	Date	Time	Depth, ft	Surface Salinity, ppt	Depth, ft	Middepth Salinity, ppt	Depth, ft	Bottom Salinity, ppt
1	8/17/01	1124	3	22.9	22.5	30.6	45	31
1	8/17/01	1236	3	28.27	24	30.8	45	30.9
1	8/17/01	1331	3	23.44	24.5	30.5	46	30.9
1	8/17/01	1458	3	23	25	31	47	31
1	8/17/01	1661	3	21.6	25.5	26.4	48	30.9
1	8/17/01	1740	3	19	25	27	47	30.8
1	8/17/01	1839	3	19	24.5	25	46	29.4
1	8/17/01	1944	3	17.9	24	23.1	45	28
1	8/17/01	2040	3	15.8	24	22.4	45	27.3
1	8/17/01	2138	3	14.9	23.5	18.4	45	27
1	8/17/01	2251	3	14.3	24	19	46	25.8
1	8/17/01	2359	3	13.9	24.5	18.8	46	25.4
1	8/18/01	0046	3	15.2	24.5	19.1	46	24.1
1	8/18/01	0154	3	16.4	23.5	24	45	24.2
1	8/18/01	0305	3	18.2	23.5	24.9	45	25.5
1	8/18/01	0415	3	21.4	23	25.7	44	30
1	8/18/01	0510	3	20.8	24	30.8	45	31.4
1	8/18/01	0603	3	23.9	25.5	30	48	31.6

Table 3
Transect R3 Salinity During 25-hr Survey

Transect	Date	Time	Depth, ft	Surface Salinity, ppt	Depth, ft	Middepth Salinity, ppt	Depth, ft	Bottom Salinity, ppt
R3	8/17/01	09:14	3	17	22	20.4	45	27.7
R3	8/17/01	10:09	3	16.8	21	22.5	42	28.7
R3	8/17/01	11:16	3	16.7	22	23.6	43	29.1
R3	8/17/01	12:56	3	16.6	22	24.4	41	29.4
R3	8/17/01	14:15	3	17.2	24	25	45	29.3
R3	8/17/01	15:20	3	18.1	24	26.2	45	29.3
R3	8/17/01	16:45	3	18.3	24	26.1	45	29.2
R3	8/17/01	17:41	3	17	24	26.3	45	29.2
R3	8/17/01	18:52	3	17.1	23	24.1	42	28.4
R3	8/17/01	20.47	3	19.6	22	21.4	42	25.5
R3	8/17/01	21.58	3	18.4	21	20.5	40	24.9
R3	8/17/01	22:57	3	17.8	21	20.1	47	23.6
R3	8/18/01	01:05	3	15.4	20	17.2	41	24.2
R3	8/18/01	02:07	3	16	22	16.9	44	23.6
R3	8/18/01	02:58	3	16	22	18.1	42	22.8
R3	8/18/01	04:06	3	16.5	24	19.5	47	24.7
R3	8/18/01	05:07	3	17.2	22	19.1	47	24.2
R3	8/18/01	06:07	3	16.6	22	20.7	44	24.8
R3	8/18/01	06:54	3	17	23	23.7	46	25
R3	8/18/01	07:45	3	17.3	22	19	46	27.3

Table 4
Transect R4 Salinity During 25-hr Survey

Transect	Date	Time	Depth, ft	Surface Salinity, ppt	Depth, ft	Middepth Salinity, ppt	Depth, ft	Bottom Salinity, ppt
R4	8/17/01	09:14	3	17	22	20.4	45	27.7
R4	8/17/01	10:09	3	16.8	21	22.5	42	28.7
R4	8/17/01	11:16	3	16.7	22	23.6	43	29.1
R4	8/17/01	12:56	3	16.6	22	24.4	41	29.4
R4	8/17/01	14:15	3	17.2	24	25	45	29.3
R4	8/17/01	15:20	3	18.1	24	26.2	45	29.3
R4	8/17/01	16:45	3	18.3	24	26.1	45	29.2
R4	8/17/01	17:41	3	17	24	26.3	45	29.2
R4	8/17/01	18:52	3	17.1	23	24.1	42	28.4
R4	8/17/01	20.47	3	19.6	22	21.4	42	25.5
R4	8/17/01	21.58	3	18.4	21	20.5	40	24.9
R4	8/17/01	22:57	3	17.8	21	20.1	47	23.6
R4	8/18/01	01:05	3	15.4	20	17.2	41	24.2
R4	8/18/01	02:07	3	19	22	20.9	44	23.6
R4	8/18/01	02:58	3	1.8	22	18.1	42	22.8
R4	8/18/01	04:06	3	16.5	24	19.5	47	24.7
R4	8/18/01	05:07	3	17.2	22	19.1	47	24.2
R4	8/18/01	06:07	3	16.6	22	20.7	44	24.8
R4	8/18/01	06:54	3	17.0	23	23.7	46	25
R4	8/18/01	07:45		17.3	22	19	46	27.3

Table 5
Transect R5 Salinity During 25-hr Survey

Transect	Date	Time	Depth, ft	Surface Salinity, ppt	Depth, ft	Middepth Salinity, ppt	Depth, ft	Bottom Salinity, ppt
R5	8/17/01	08:55	3	17.4	24	23.2	45	26.3
R5	8/17/01	09:50	3	16.9	22	24.6	45	27.6
R5	8/17/01	11:00	3	17.0	23	24.9	43	28.6
R5	8/17/01	12:39	3	19.1	18	22.9	43	24.1
R5	8/17/01	13:56	3	18.1	24	26.6	45	28.5
R5	8/17/01	15:02	3	17.5	22	24.4	42	29.0
R5	8/17/01	16:28	3	16.6	22	24.5	41	29.2
R5	8/17/01	17:24	3	17.0	24	26.9	45	29.0
R5	8/17/01	18:36	3	17.4	23	22.7	43	26.7
R5	8/17/01	20:26	3	20.9	23	23.6	45	26.3
R5	8/17/01	21:45	3	19.1	21	20.2	43	25.2
R5	8/17/01	22:39	3	18	22	20	45	25.8
R5	8/17/01	00:53	3	14	22	19.7	42	22.7
R5	8/18/01	01:59	3	13.4	23	18.6	46	24.3
R5	8/18/01	02:39	3	13.3	24	16.6	46	24.9
R5	8/18/01	03:49	3	17.1	26	21.1	45	23.1
R5	8/18/01	04:50	3	16.2	22	19.9	46	23.4
R5	8/18/01	05:50	3	17.6	21	20.9	45	23.7
R5	8/18/01	06:37	3	17.7	23	22.7	46	24.3
R5	8/18/01	07:29	3	17.5	23	21.2	45	23.0

Table 6
Transect R6 Salinity During 25-hr Survey

Transect	Date	Time	Depth, ft	Surface Salinity, ppt	Depth, ft	Middepth Salinity, ppt	Depth, ft	Bottom Salinity, ppt
R6	8/17/01	07:15	3	8.4	25.3	15.8	47.6	17.3
R6	8/17/01	08:40	3	9.0	22.5	16	42	19.2
R6	8/17/01	09:21	3	8.8	25.5	16.4	48	19.8
R6	8/17/01	10:37	3	9.2	24.5	17.9	46	20
R6	8/17/01	11:04	3	8.7	25	18.5	47	20
R6	8/17/01	12:40	3	8.4	24.5	19.4	46	19.9
R6	8/17/01	13:10	3	8.6	24.5	19	46	20.1
R6	8/17/01	14:49	3	8.9	25	17.9	47	19.1
R6	8/17/01	15:07	3	9.5	22.5	18.5	42	19.7
R6	8/17/01	16:33	3	9.7	25	17.5	47	19.6
R6	8/17/01	17:10	3	10.1	24.6	17.3	46.5	19
R6	8/17/01	18:17	3	9.8	25	16.2	47	19.4
R6	8/17/01	19:06	3	9.9	24.5	15.4	46	19.3
R6	8/17/01	20:09	3	8.9	25	15.4	47	19
R6	8/17/01	21:14	3	9.7	25	14.1	47	19
R6	8/17/01	22:14	3	8.8	23.5	13.4	44	19
R6	8/17/01	23:05	3	8.8	23	12.5	43	19
R6	8/18/01	01:18	3	8.6	24.5	11.5	46	19.1
R6	8/18/01	02:10	3	8.6	21.5	10.3	40	17.9
R6	8/18/01	03:06	3	8.7	24.5	10.8	46	18.9
R6	8/18/01	04:07	3	8.7	24.5	11.5	46	17.9
R6	8/18/01	05:09	3	8.3	25	12.4	47	16.8
R6	8/18/01	06:03	3	8.5	25	14.8	47	16.2
R6	8/18/01	07:37	3	9.8	25	15.5	47	15.9
R6	8/18/01	08:06	3	9.9	25	15.2	47	16.7

Table 7
Transect R7 Salinity During 25-hr Survey

Transect	Date	Time	Depth, ft	Surface Salinity, ppt	Depth, ft	Middepth Salinity, ppt	Depth, ft	Bottom Salinity, ppt
R7	8/17/01	07:30	3	11.1	17.5	15		
R7	8/17/01	08:24	3	10.3	18	14.6		
R7	8/17/01	09:37	3	11.6	17.5	15		
R7	8/17/01	10:27	3	9.9	17.5	16.3		
R7	8/17/01	11:14	3	12.7	17.5	16.7		
R7	8/17/01	12:24	3	11.7	17.2	17.2		
R7	8/17/01	13:18	3	11.9	18	17.2		
R7	8/17/01	14:35	3	10.8	17.5	17.3		
R7	8/17/01	15:16	3	9.9	17	16.4		
R7	8/17/01	16:22	3	9.9	17.5	15		
R7	8/17/01	17:31	3	10.4	17.2	14.4		
R7	8/17/01	18:04	3	11.5	17.5	15.3		
R7	8/17/01	19:21	3	10.4	17.5	13.4		
R7	8/17/01	20:26	3	10.2	17	11.8		
R7	8/17/01	21:28	3	9.8	17.5	11.5		
R7	8/17/01	22:42	3	10.2	17.5	10.9		
R7	8/17/01	23:21	3	9.3	16.5	10.2		
R7	8/18/01	01:32	3	6.8	17	8.8		
R7	8/18/01	02:48	3	6.4	17.5	9.2		
R7	8/18/01	03:20	3	6.7	17.5	10.7		
R7	8/18/01	04:21	3	7	17	11.2		
R7	8/18/01	05:22	3	9.9	17.5	10.3		
R7	8/18/01	06:15	3	10.9	17.5	14.2		
R7	8/18/01	07:26	3	11.8	17.5	14.4		
R7	8/18/01	08:18	3	12.4	17.5	15.2		

Table 8
Transect R10 Salinity During 25-hr Survey

Transect	Date	Time	Depth, ft	Surface Salinity, ppt	Depth, ft	Middepth Salinity, ppt	Depth, ft	Bottom Salinity, ppt
R10	8/17/01	07:51	3	2.1	8	2.1	13	2.2
R10	8/17/01	08:06	3	2.1	8	2.1	13	2.1
R10	8/17/01	09:00	3	2.1	7.5	2	12	1.8
R10	8/17/01	10:08	3	2.1	8	2.1	12	2.1
R10	8/17/01	11:08	3	2.1	8	2.1	13	2.1
R10	8/17/01	12:09	3	2	7.5	2	12	2
R10	8/17/01	13:06	3	2	8	2	13	2
R10	8/17/01	14:16	3	2	8	2	13	2
R10	8/17/01	15:06	3	1.8	7.5	2	12	2
R10	8/17/01	16:08	3	1.8	8	2	13	2
R10	8/17/01	17:07	3	1.8	7.5	1.8	11	1.8
R10	8/17/01	18:08	3	1.8	8	1.8	13	1.8
R10	8/17/01	19:09	3	1	7.5	1	12	1
R10	8/17/01	20:08	3	1	8	1	13	1
R10	8/17/01	21:17	3	1	7	1	11	1
R10	8/17/01	22:14	3	1	7.5	1	12	1
R10	8/17/01	23:10	3	1.7	8	1	11	1
R10	8/18/01	00:09	3	1.8	7.5	1.8	12	1.8
R10	8/18/01	01:09	3	1.8	7.5	1.8	12	1.8
R10	8/18/01	02:09	3	1.8	7.5	1.8	13	1.8
R10	8/18/01	03:13	3	1.8	7.5	1.8	12	1.8
R10	8/18/01	04:14	3	1.5	7.5	1.5	13	1.5
R10	8/18/01	05:09	3	1.5	8	1.5	13	1.5
R10	8/18/01	06:12	3	1.5	8	1.5	13	1.5
R10	8/18/01	07:07	3	1.5	8	1.5	13	1.5
R10	8/18/01	08:07	3	1.5	7.5	1.5	12	1.5

Table 9
Sabine Neches Waterway Equipment Deployment Locations

Station No.	Location	Latitude North Deg min sec	Longitude West Deg min sec	Data Type	Distance of Reference point to sensor, ft	Sensor Zero Elev. NAVD88	Height of sensor above bottom, ft
1	Upper Beaumont- Pine Island	30° 09’ 33.65”	94° 06’ 57.34”	Salinity	6.83	-4.98	
		30° 09’ 33.65”	94° 06’ 57.34”	Tide	Lost sensor	--	--
2	Beaumont- Neches River	30° 04’ 40.78”	94° 03’ 49.19”	Salinity	8.74	-2.28	
		30° 04’ 40.78”	94° 03’ 49.19”	Tide	8.74	-2.28	
		29° 59’ 03.76”	93° 54’ 18.44”	Tide	10.33	-1.50	
3	Rainbow Bridge- Neches River	29° 59’ 03.76”	93° 54’ 18.44”	Salinity	10.83	-2.00	
		29° 59’ 03.76”	93° 54’ 18.44”	Current	7.9	0.93	
		29° 59’ 31.15”	93° 47’ 02.21”	Tide	8.5	-0.17	
		29° 59’ 31.82”	93° 47’ 02.83”	Current			7.1
4	Sabine River	29° 59’ 31.82”	93° 47’ 02.83”	Current			11.37
5	Sabine River- Orange, TX	30° 06’ 45.96”	93° 42’ 11.61”	Tide	8.62	-1.57	
		30° 06’ 45.96”	93° 42’ 11.61”	Salinity	11.5	-2.97	3.6
6	Sabine-Neches Canal- Port Arthur, TX	29° 51’ 59.90”	93° 55’ 52.26”	Tide	11.36	-4.90	
		29° 51’ 59.90”	93° 55’ 52.26”	Salinity	11.87		
		29° 51’ 59.90”	93° 55’ 52.26”	Current	Removed 09/01		

Table 9 (Continued)
Sabine Neches Waterway Equipment Deployment Locations

Station No.	Location	Latitude North Deg min sec	Longitude West Deg min sec	Data Type	Distance of Reference point to sensor, ft	Sensor Zero Elev. NAVD88	Height of sensor above bottom, ft
7	Sabine Pass Channel	29° 41' 37.13"	93° 50' 18.77"	Salinity	Unavailable	Unavailable	3.2
		29° 41' 37.13"	93° 50' 18.77"	Current	Unavailable	Unavailable	3.2
9	Upper Sabine Lake	29° 58' 43.00"	93° 47' 13.72"	Tide	8.2	-1.13	
		29° 58' 43.00"	93° 47' 13.72"	Salinity	8.2	-1.13	
		29° 58' 43.00"	93° 47' 13.72"	Current			2.5
10	Lower Sabine Lake	29° 47' 37.85"	93° 54' 18.09"	Tide	8	-3.25	
		29° 47' 37.85"	93° 54' 18.09"	Salinity	8	-3.25	
		29° 45' 55.90"	93° 45' 23.57"	Current	7.94	-.046	
11	Blacks Bayou	29° 59' 49.18"	93° 45' 23.57"	Tide	8.45	-2.45	
		29° 59' 49.18"	93° 45' 23.57"	Salinity	8.4	-2.40	
		29° 59' 49.18"	93° 45' 23.57"	Current	11.77	-4.29	3.02
12	GIWW East	30° 03' 34.94"	93° 32' 25.27"	Tide	12.27		1.15
		30° 03' 34.94"	93° 32' 25.27"	Salinity	12.83		0.67
				Current	9.34	-2.4	0.68
13	GIWW West	29° 40' 49.49"	94° 11' 57.83"	Tide	Unavailable	Unavailable	1.23
		29° 40' 49.49"	94° 11' 57.83"	Salinity	Unavailable	Unavailable	0.66
		29° 40' 49.49"	94° 11' 57.83"	Current	Unavailable	Unavailable	2.6

Table 9 (Concluded)
Sabine Neches Waterway Equipment Deployment Locations

Station No.	Location	Latitude North Deg min sec	Longitude West Deg min sec	Data Type	Distance of Reference point to sensor, ft	Sensor Zero Elev. NAVD88	Height of sensor above bottom, ft
14	Johnson's Bayou	29° 50' 52.23"	93° 46' 52.12"	Tide	8.76	-4.56	
		29° 50' 52.23"	93° 46' 52.12"	Salinity	9.29	-5.10	
		29° 50' 52.23"	93° 46' 52.12"	Current	8.58		
15	Keith Lake	29° 46' 28.85"	93° 56' 39.45"	Tide	16.14	Unavailable	
		29° 46' 28.85"	93° 56' 39.45"	Salinity	16.14	Unavailable	
16	Willow Bayou	29° 52' 41.69"	93° 46' 10.45"	Tide	8.52	-3.14	
		29° 52' 41.69"	93° 46' 10.45"	Salinity	9.03	-3.65	

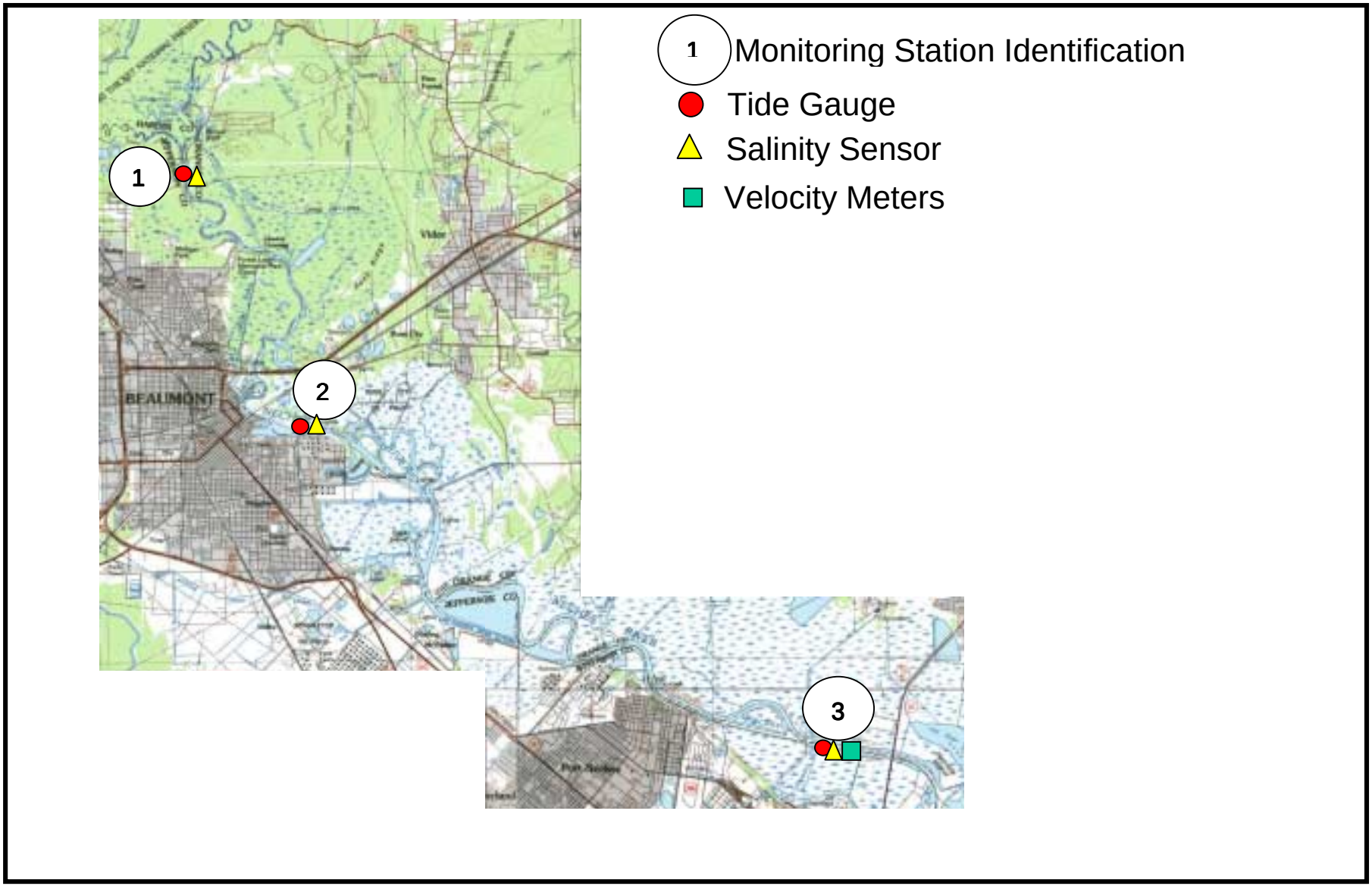

Figure 1. Instrument locations in the Neches River, from Pine Island Bayou to the Rainbow Bridge.

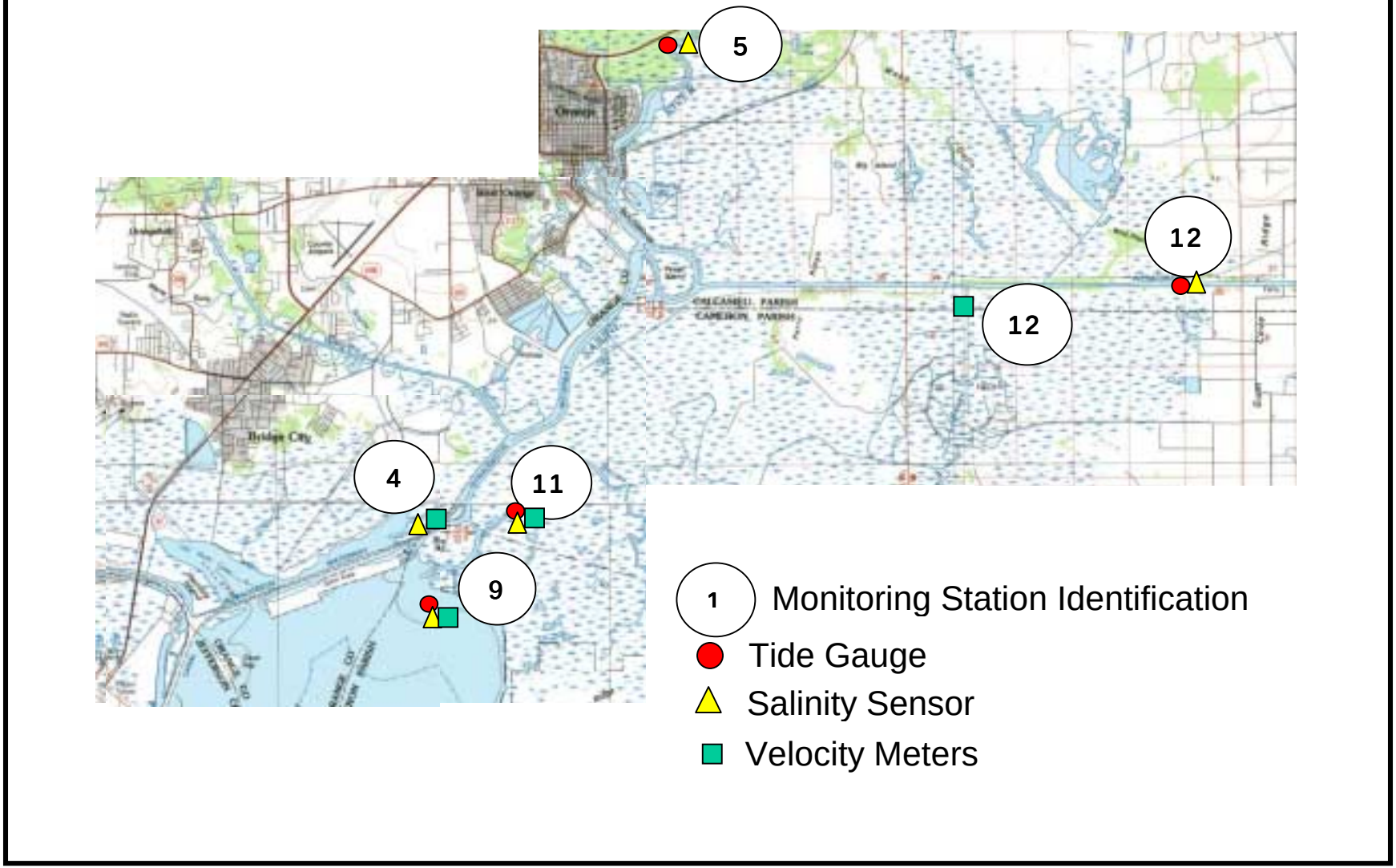

Figure 2. Instrument locations in Sabine River, Upper Sabine Lake, Blacks Bayou and the GIWW east.

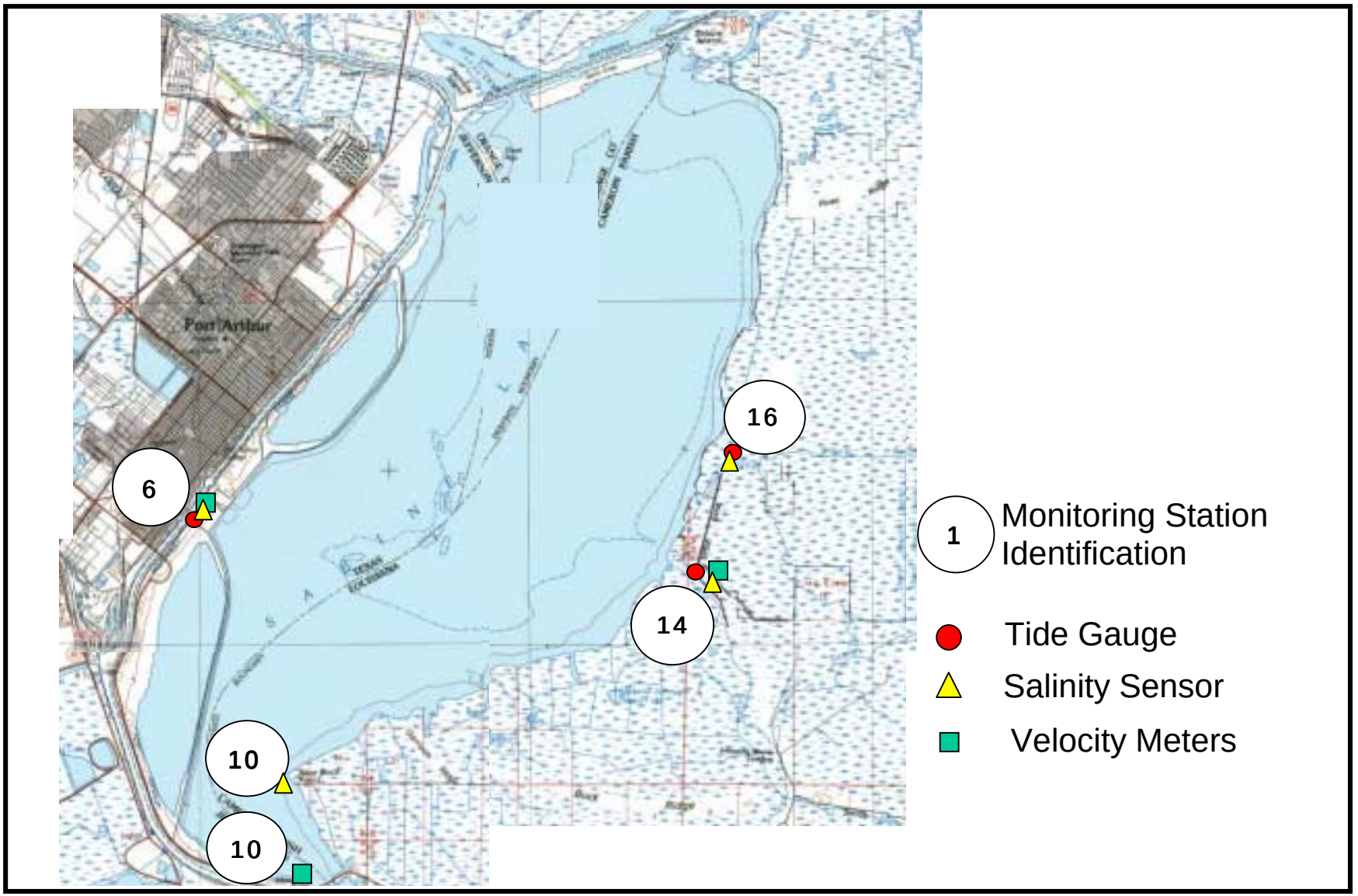

Figure 3. Instrument locations in Sabine Neches Canal, Lower Sabine Lake, Johnson Bayou and Willow Bayou.

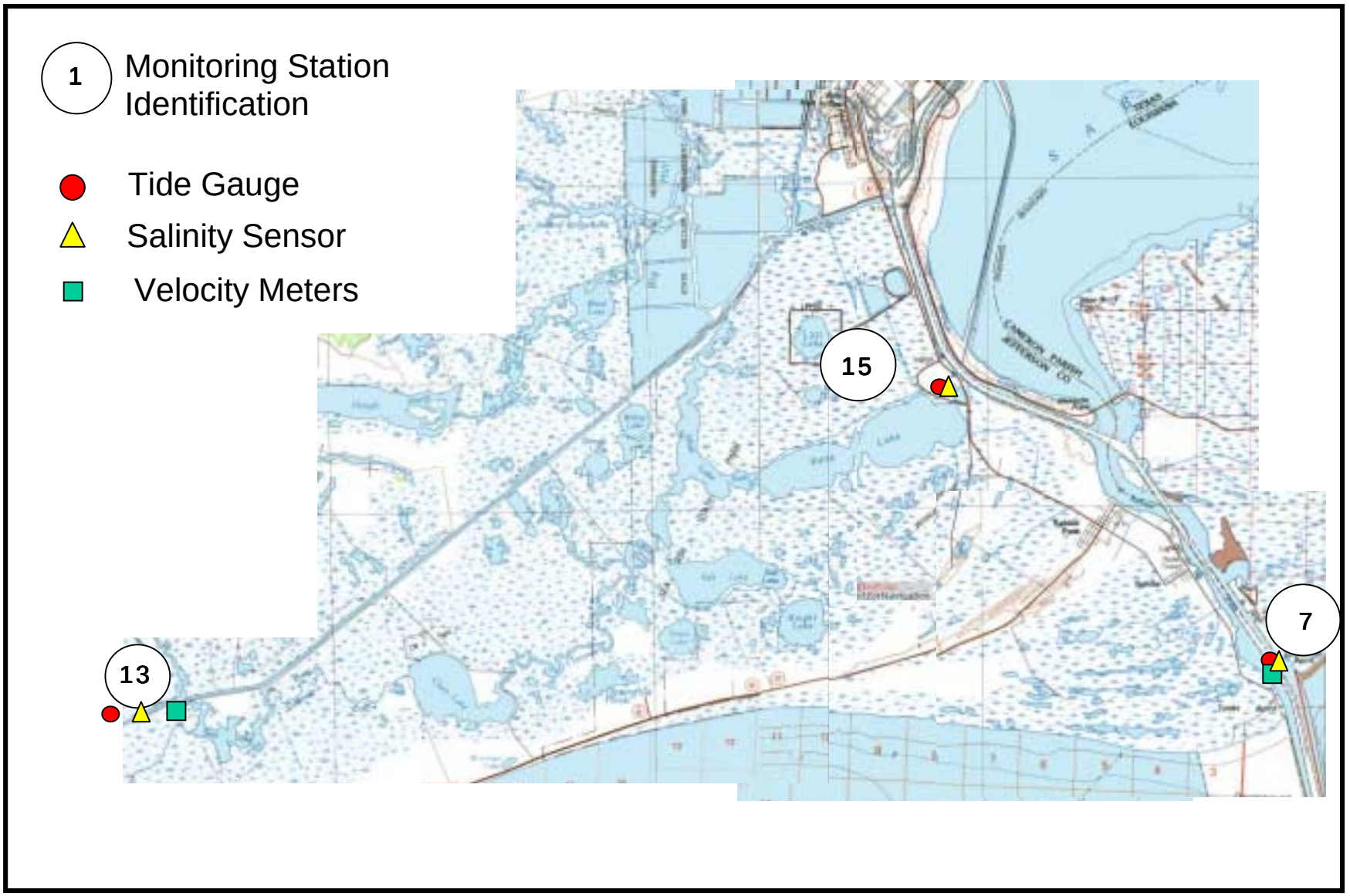

Figure 4. Instrument locations in Sabine Pass Channel, Keith Lake, and GIWW west.

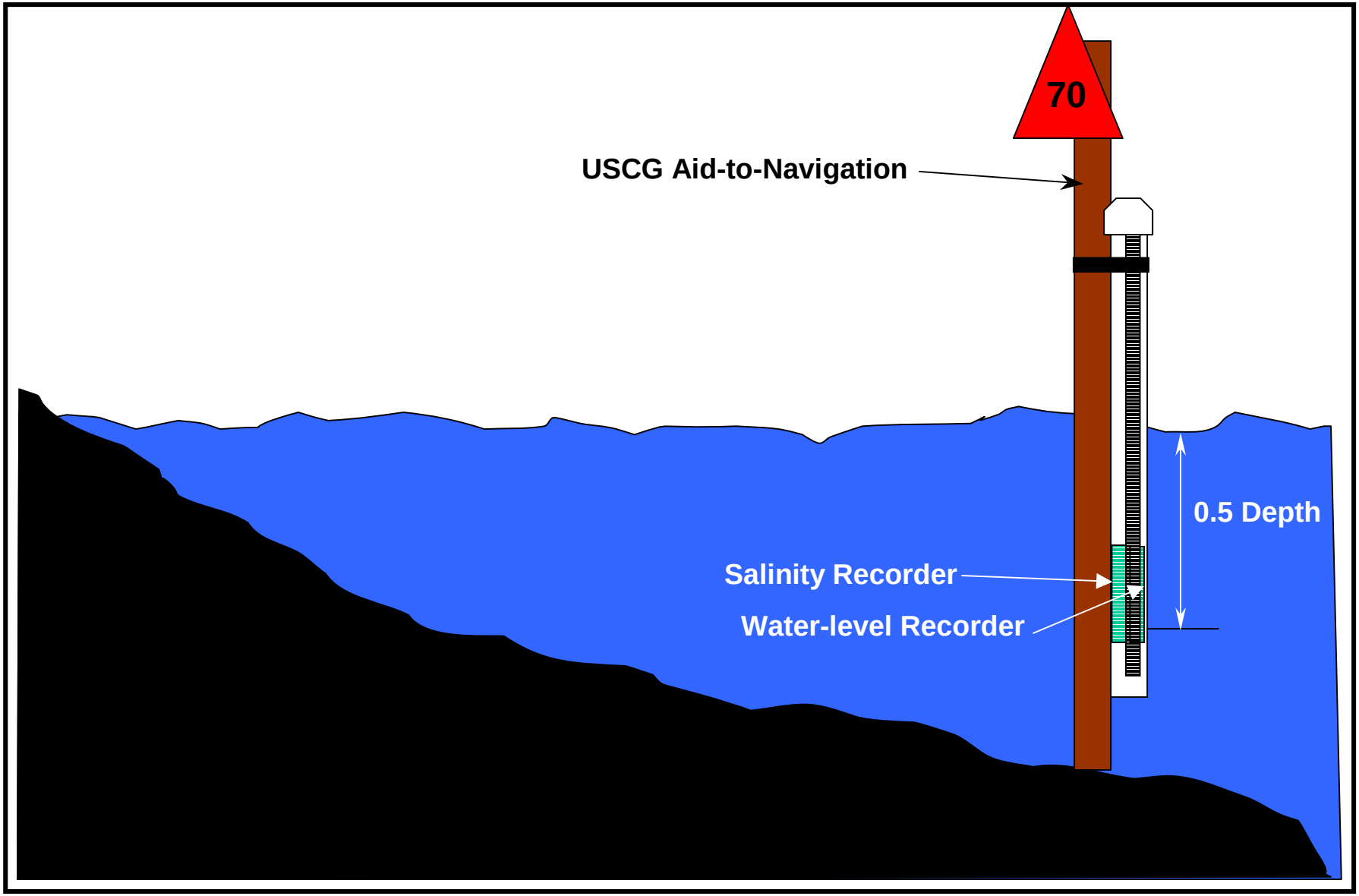

Figure 5. Typical deployment of water-level and salinity recorders on and existing USCG Aid-to-Navigation (ATON).

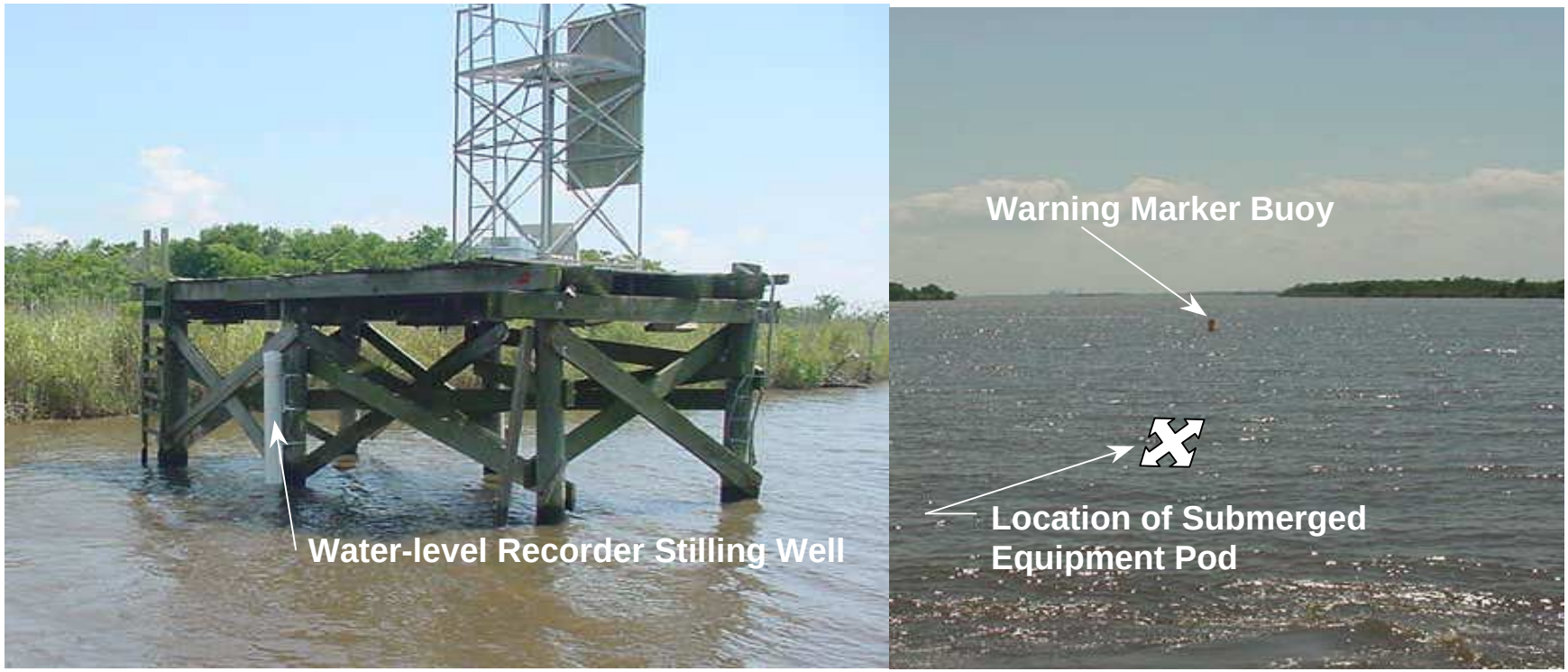

Figure 6. Photograph of instruments at Station 4, Sabine River, using the USCG Range Marker platform to deploy the water-level recorder and the deployment of the submerged equipment pod.

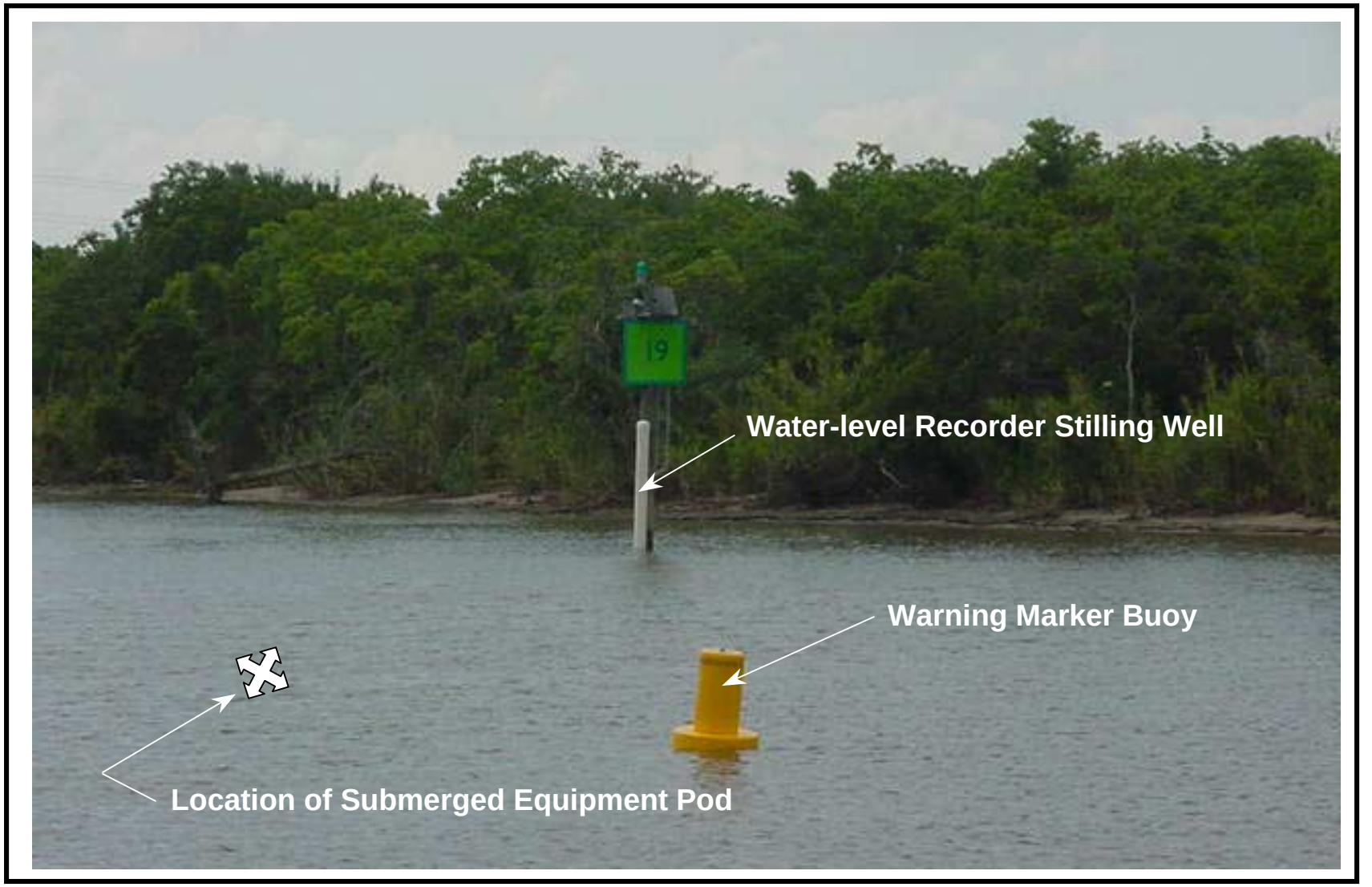

Figure 7. Photograph of the instrument deployments at Station 3, Neches River, using a USCG Channel Marker for the water level recorder.

Figure 8. Instrument deployment at Station 2, Neches River, using a USCG Channel marker for deploying the water-level and salinity recorder.

Figure 9. Instrument deployment at Station 7, Sabine Pass, using a USCG Range Marker platform for mounting the stilling well.

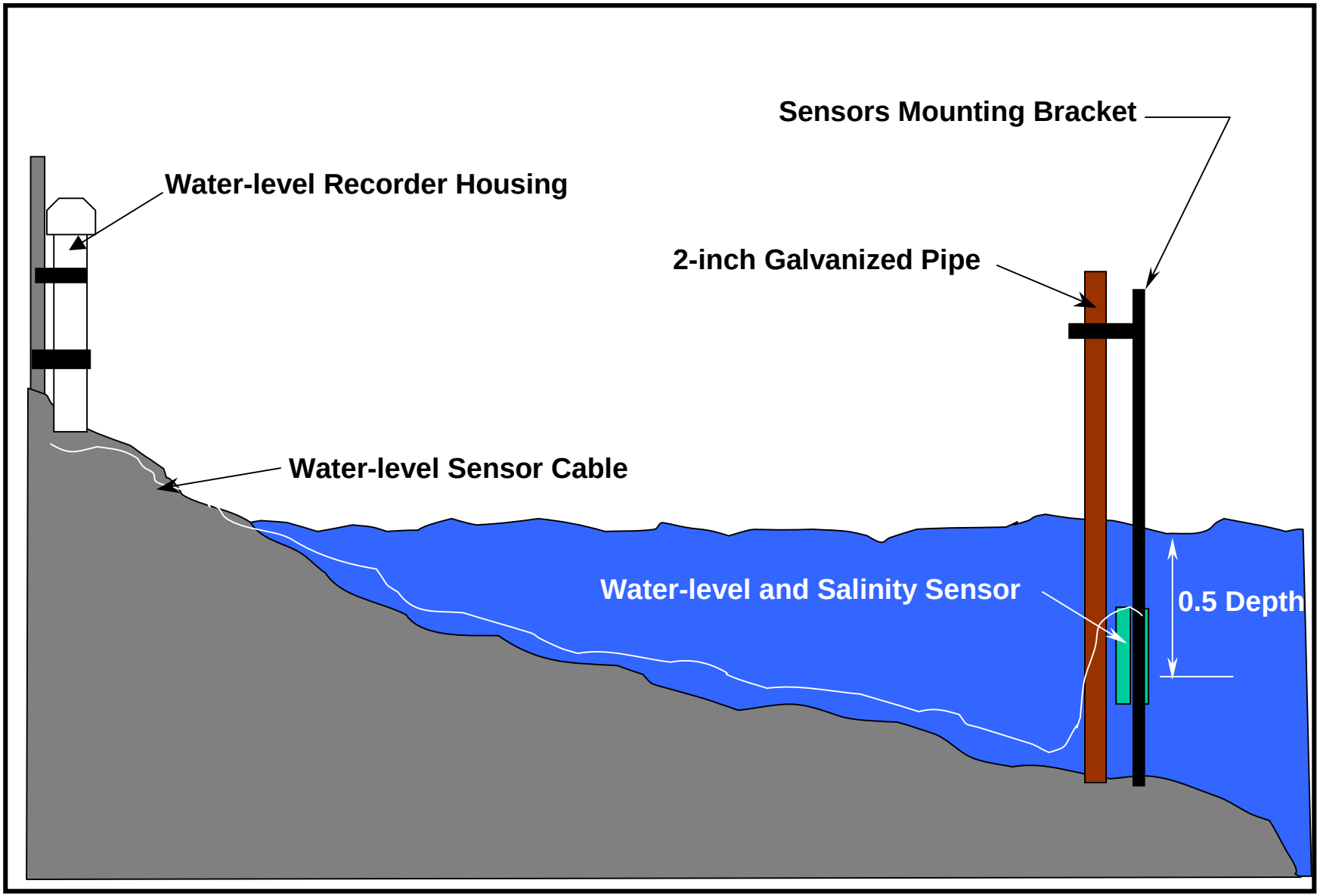

Figure 10. Typical deployment used when no USCG Aids-to-Navigation are available for use.

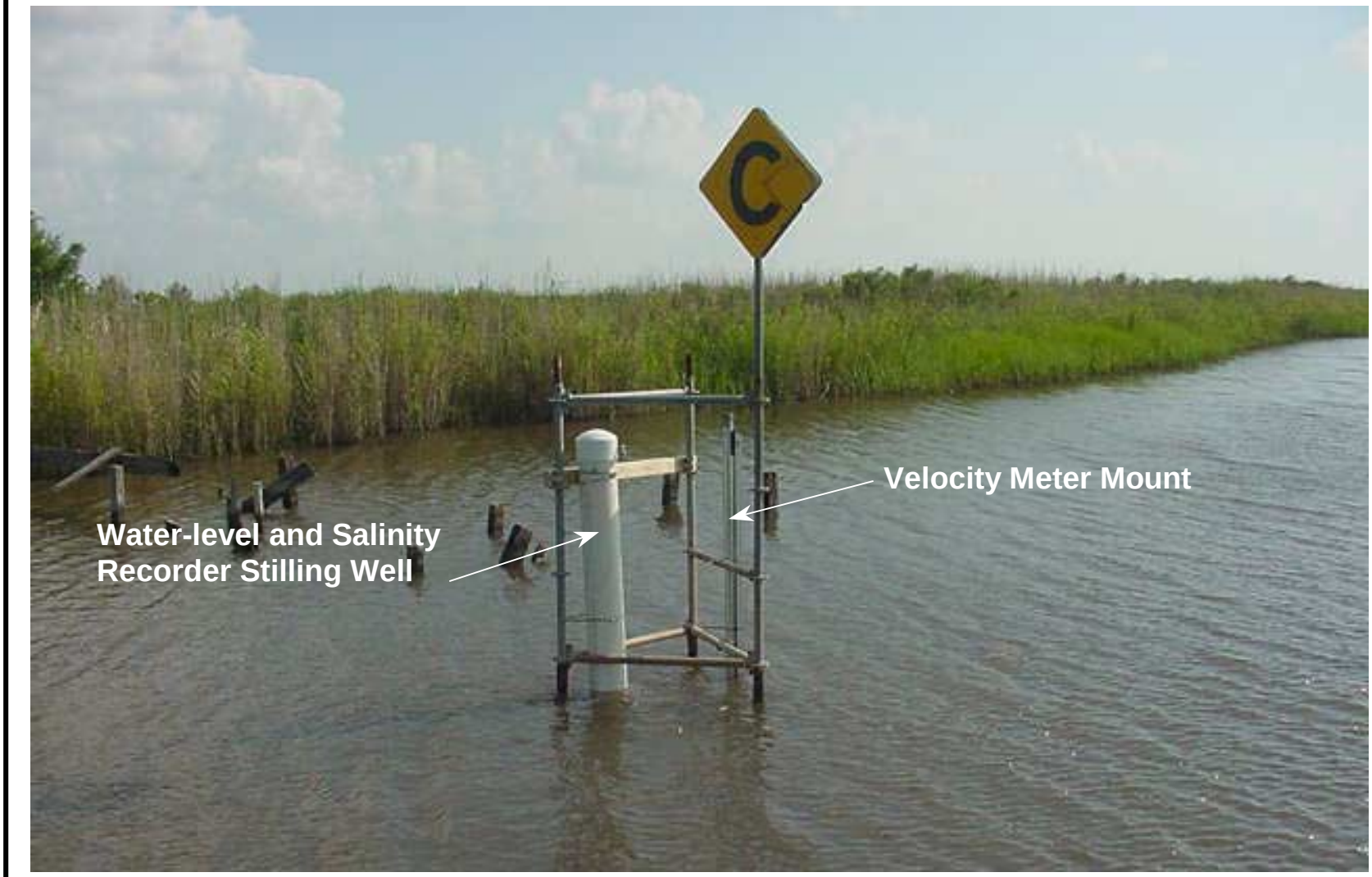

Figure 11. Instrument deployment at Station 11, Blacks Bayou, using an existing structure left from a previous study.

Figure 12. Photograph of the YSI® 600R Conductivity, Temperature, Depth (CTD) sensor.

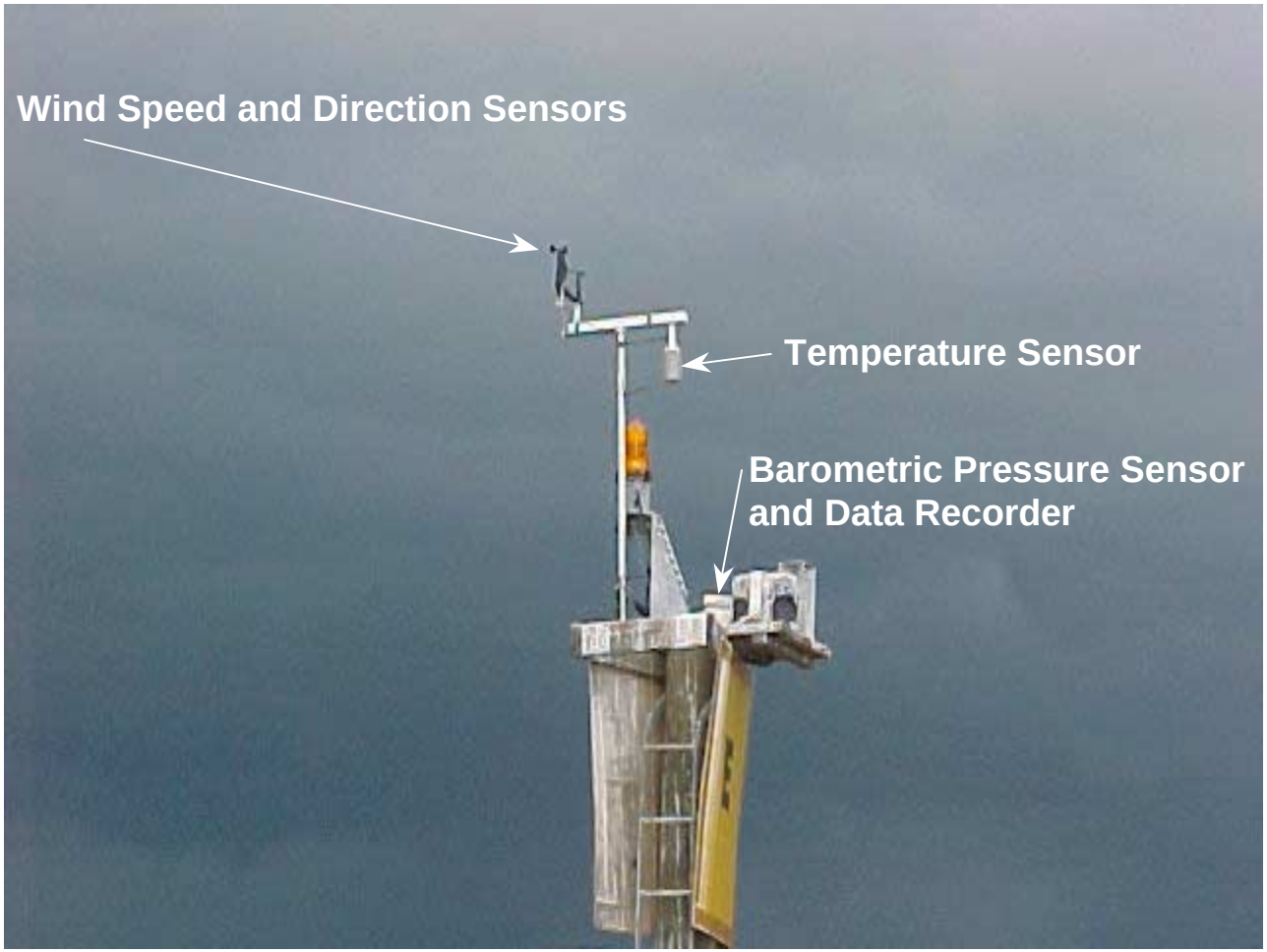

Figure 13. Meteorological recoding station Model W2000.

Figure 14. Photograph of the Aquadopp® Acoustic Doppler Velocity meter (ADV).

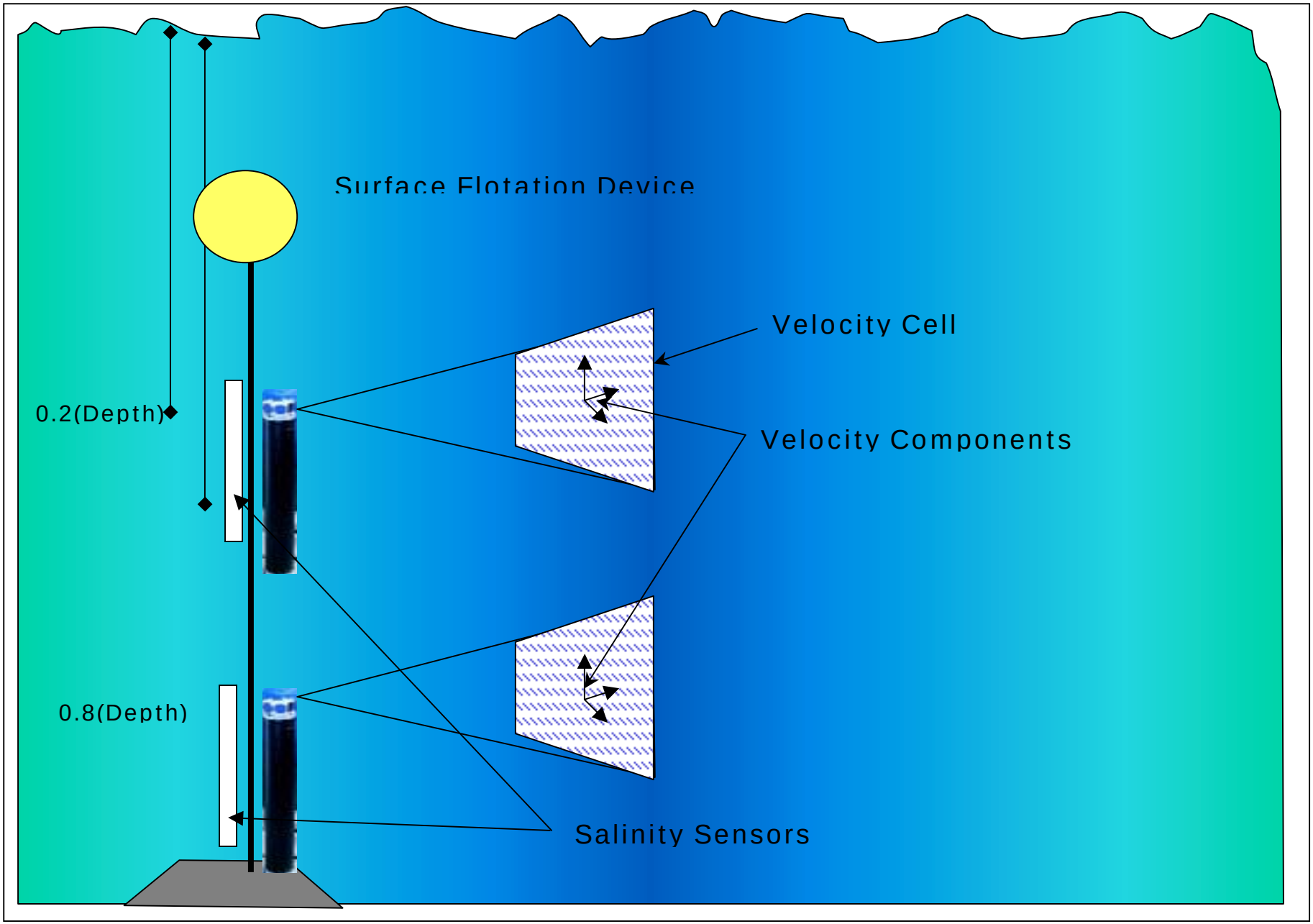

Figure 15. Typical deployment of the ADV and the salinity sensors near the channel.

Figure 16. Biological growth on submerged instrumentation could be heavy during the warm summer months.

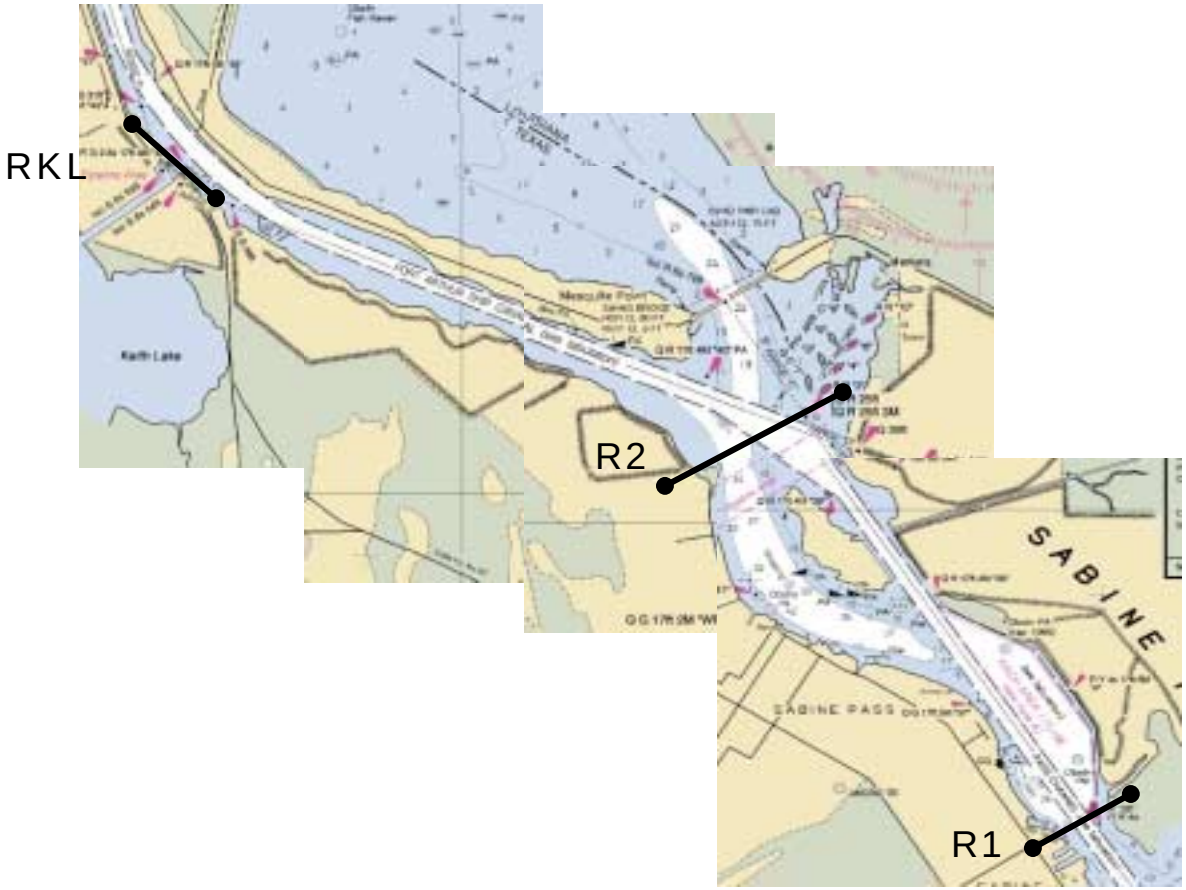

Figure 17. 25 hr velocity data collection locations for Boat No. 1

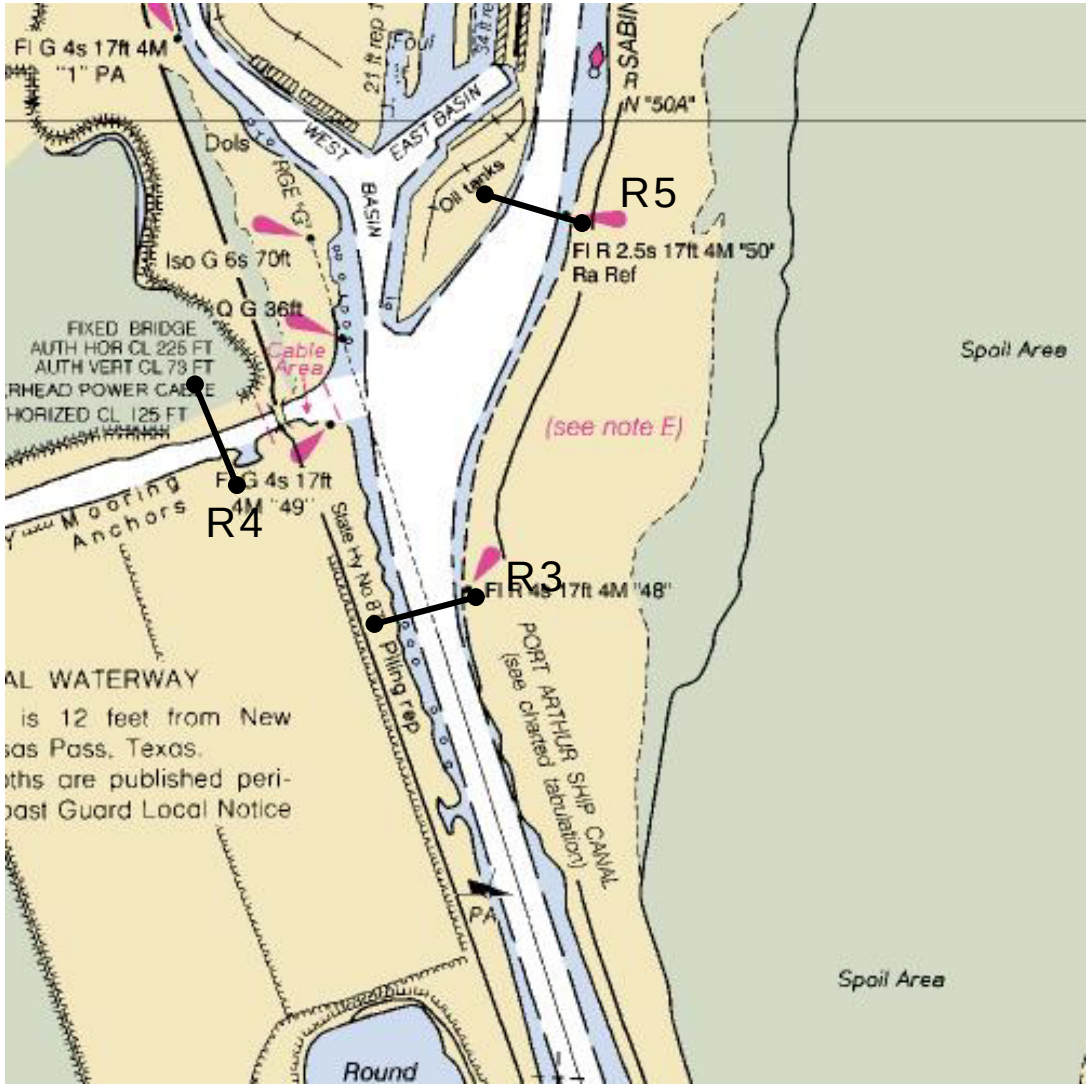

Figure 18. 25-hour velocity data collection transect locations for Boat No. 2

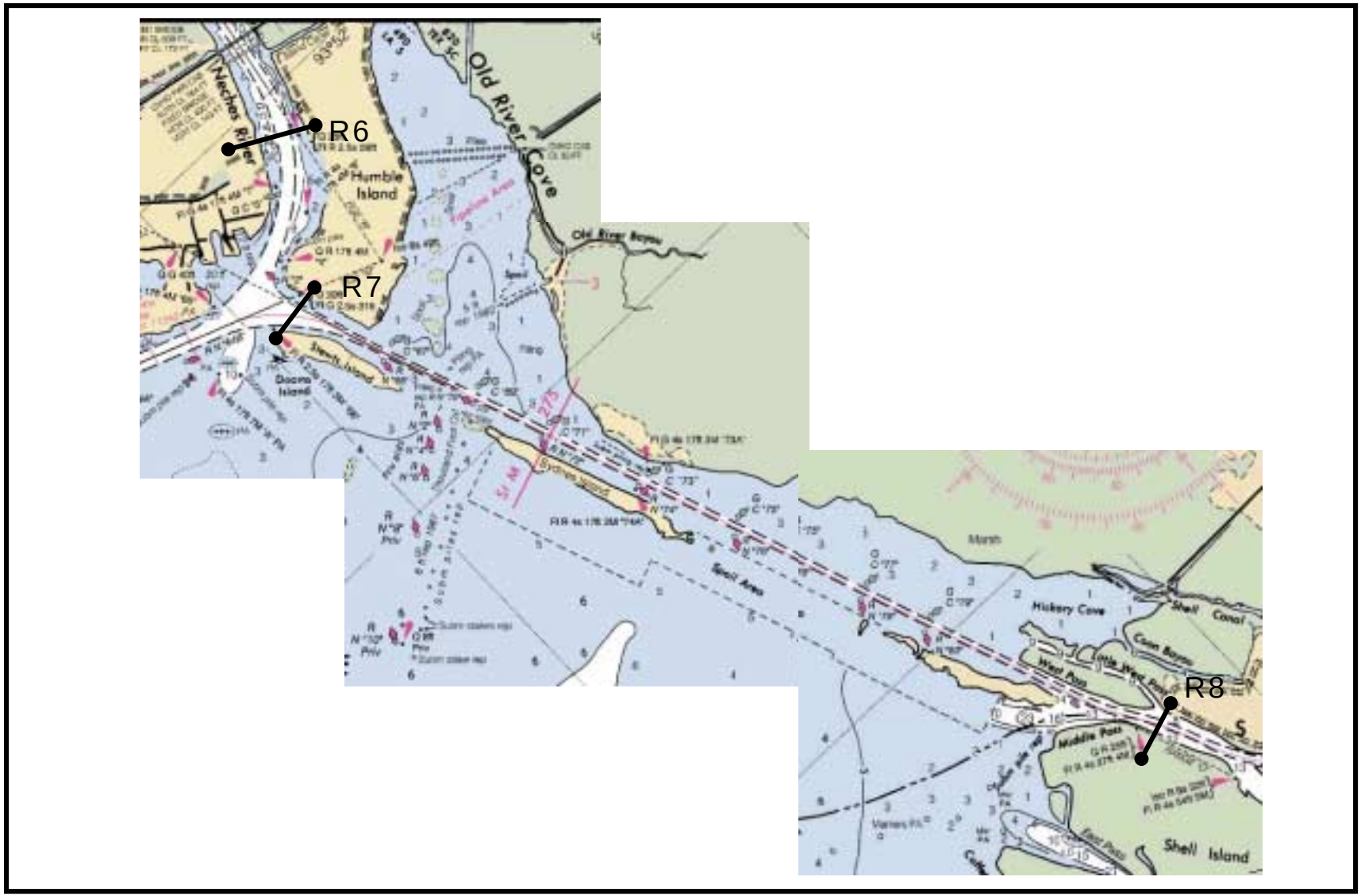

Figure 19. 25-hour velocity data collection transect locations for Boat No. 3

Figure 20. 25-hour velocity data collection transect locations for Boat No. 4

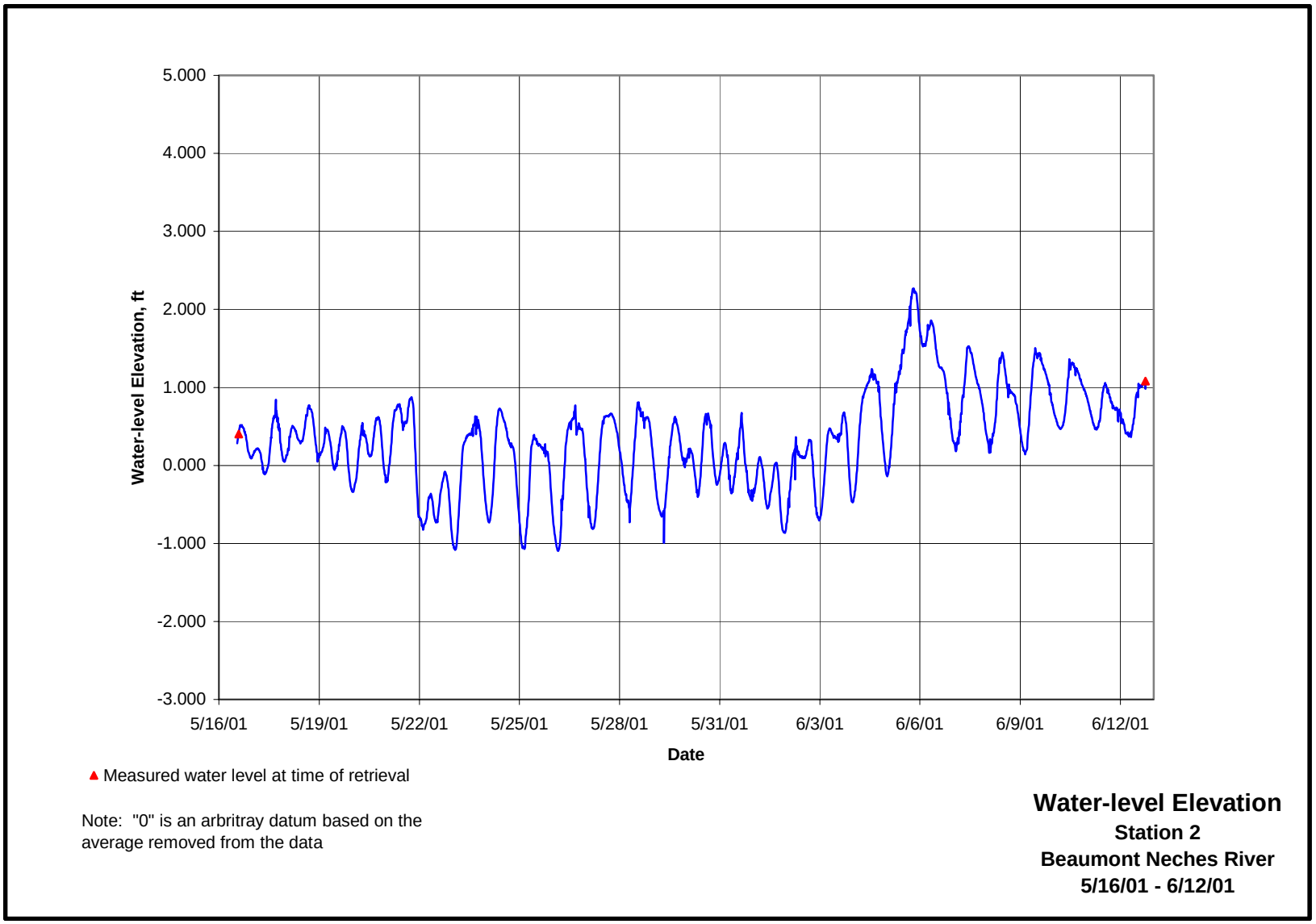

Figure 21. Water-level elevation record for Station 2 from 5/16/01 – 6/12/01.

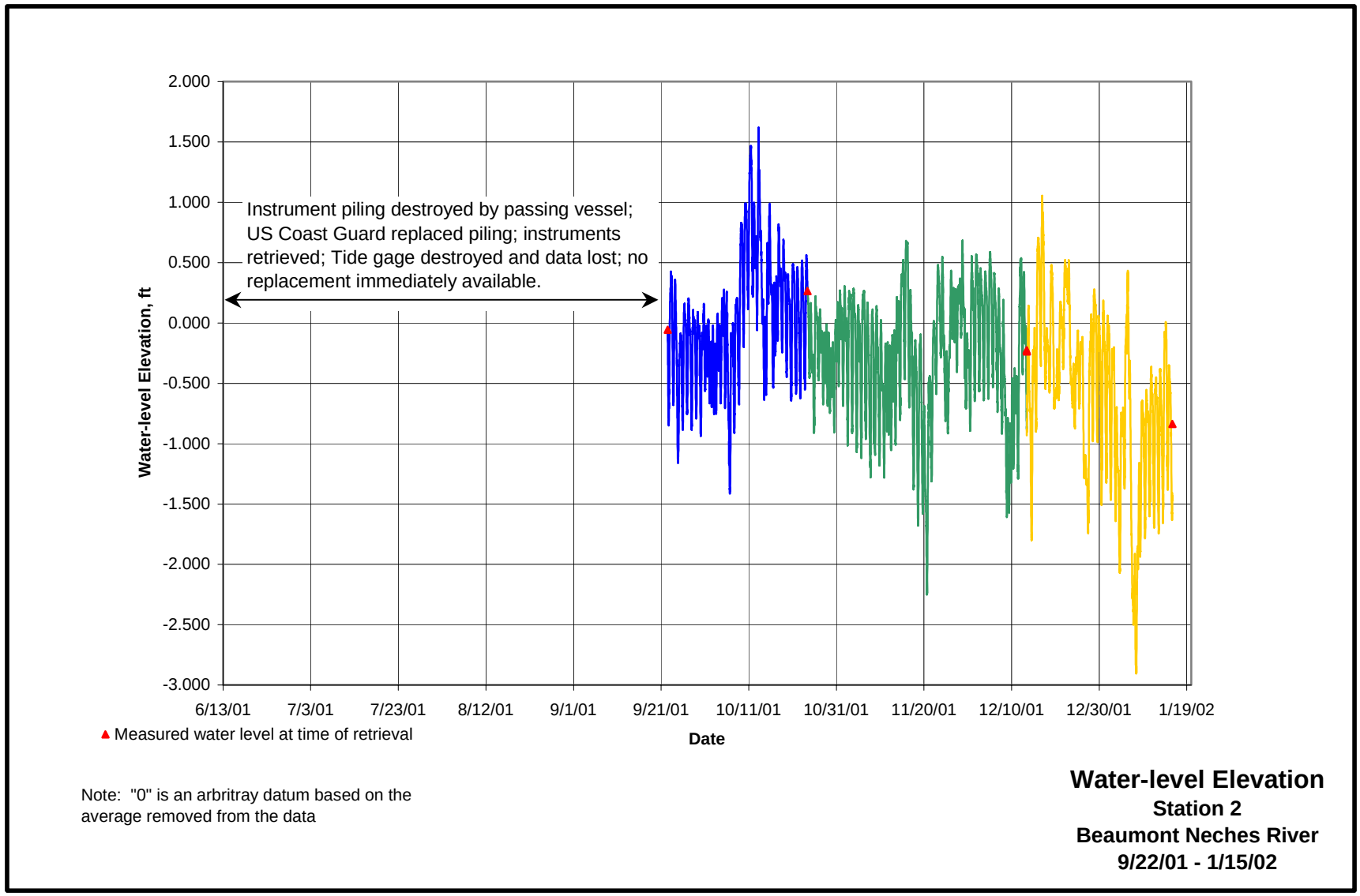

Figure 22. Water-level elevation record for Station 2 from 9/22/01 – 01/15/02.

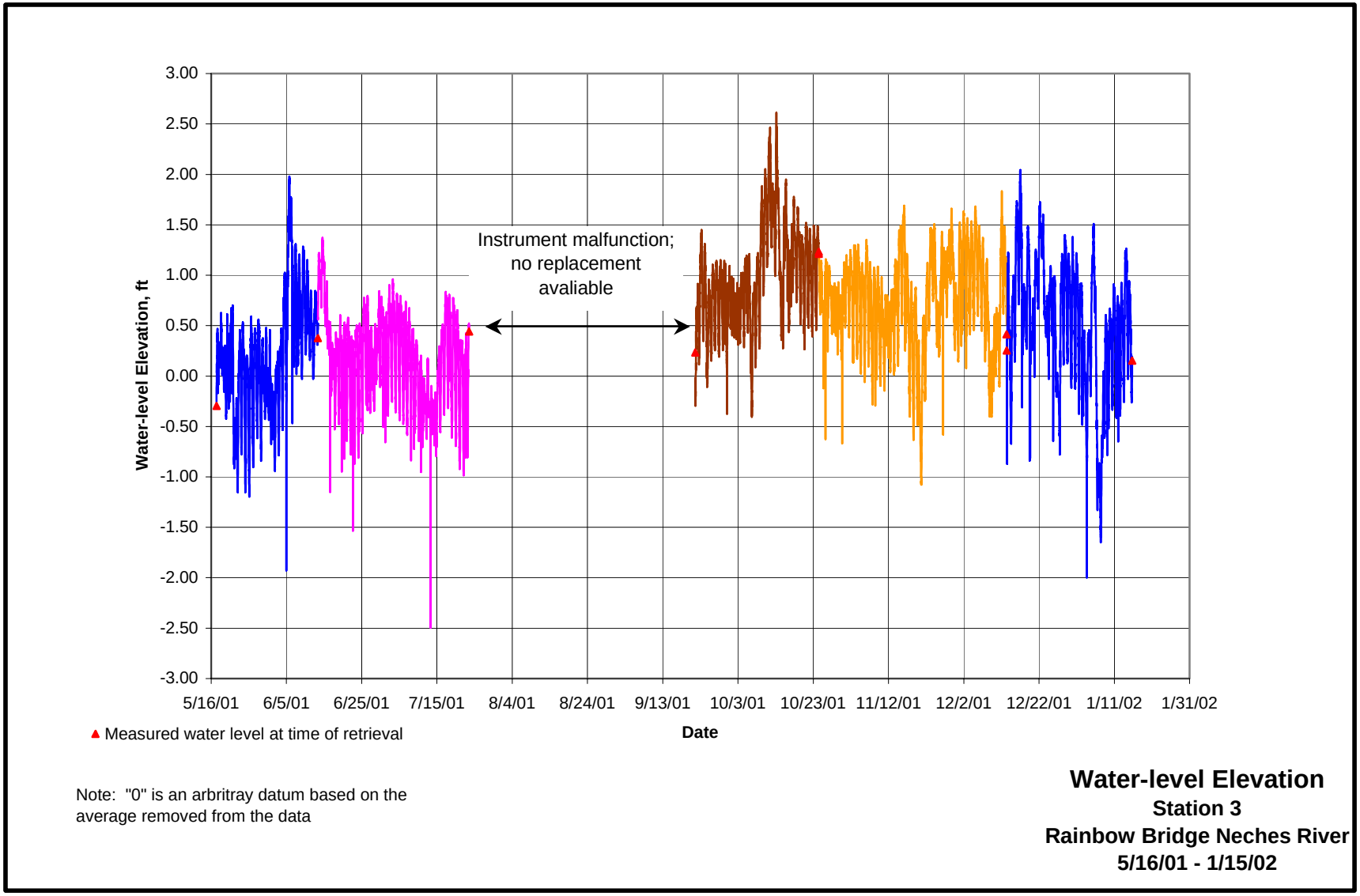

Figure 23. Water-level elevation record for Station 3 from 5/16/01 – 01/15/02.

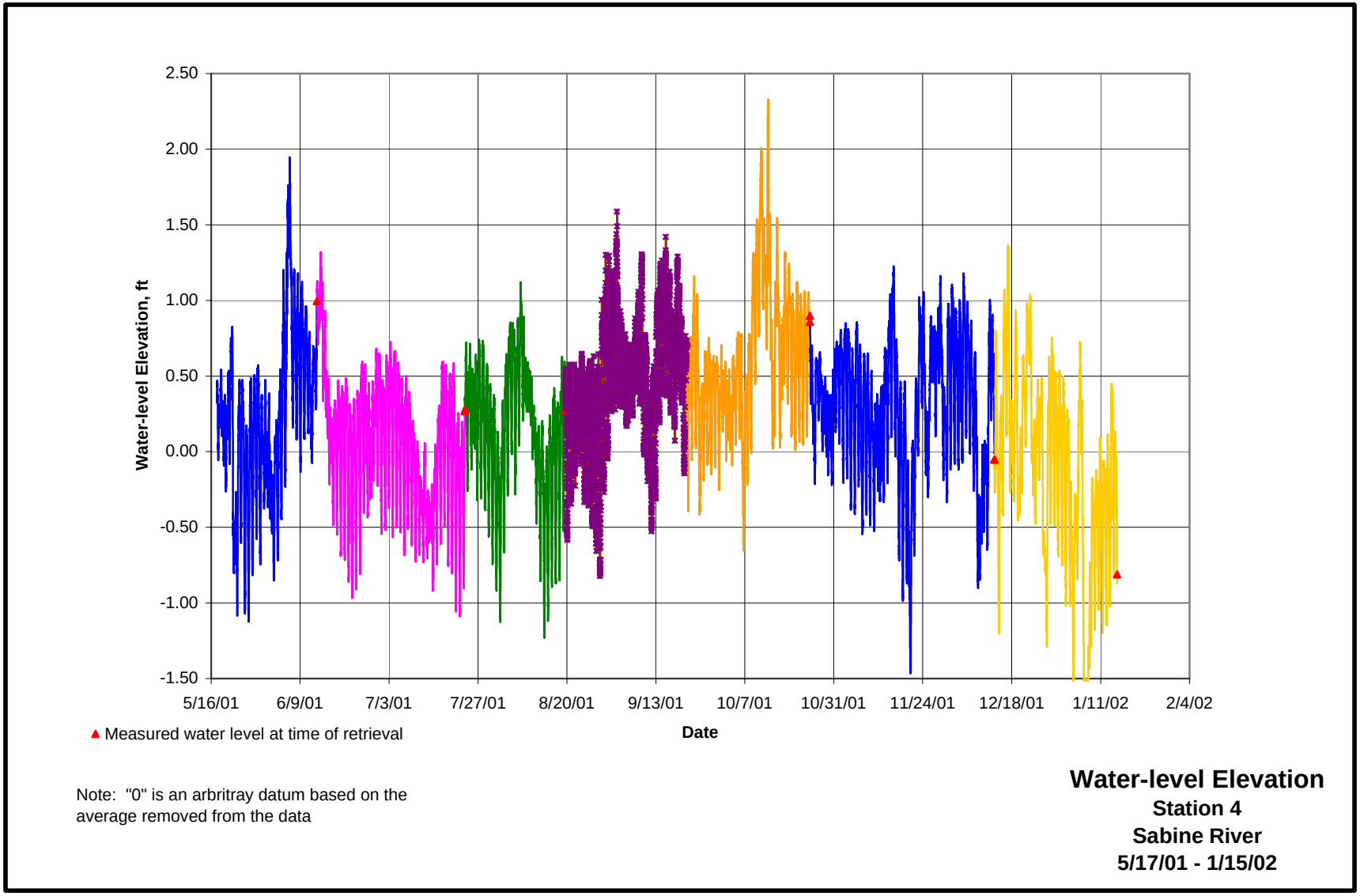

Figure 24. Water-level elevation record for Station 4 from 5/17/01 – 01/15/02.

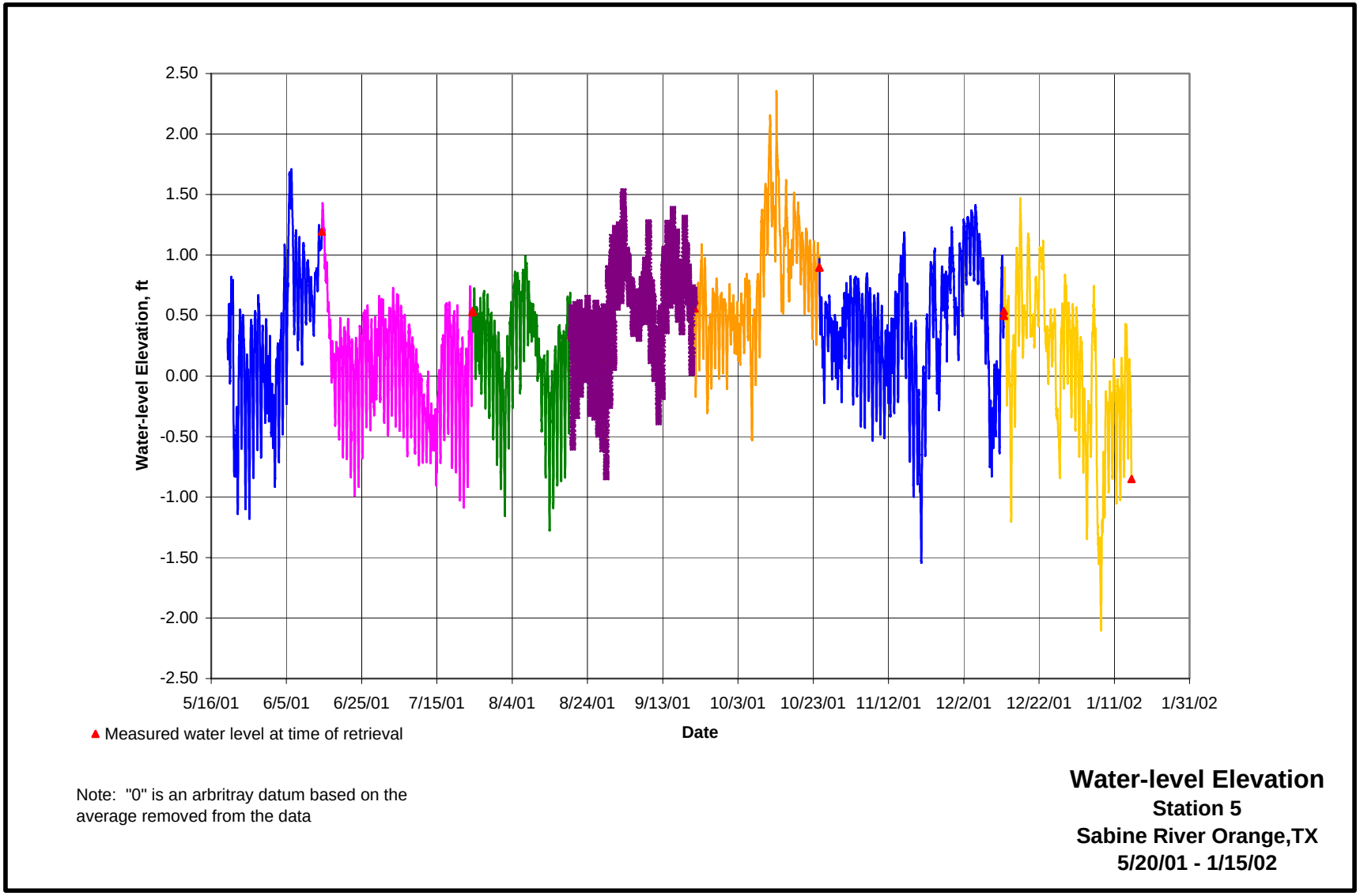

Figure 25. Water-level elevation record for Station 5 from 5/20/01 – 01/15/02.

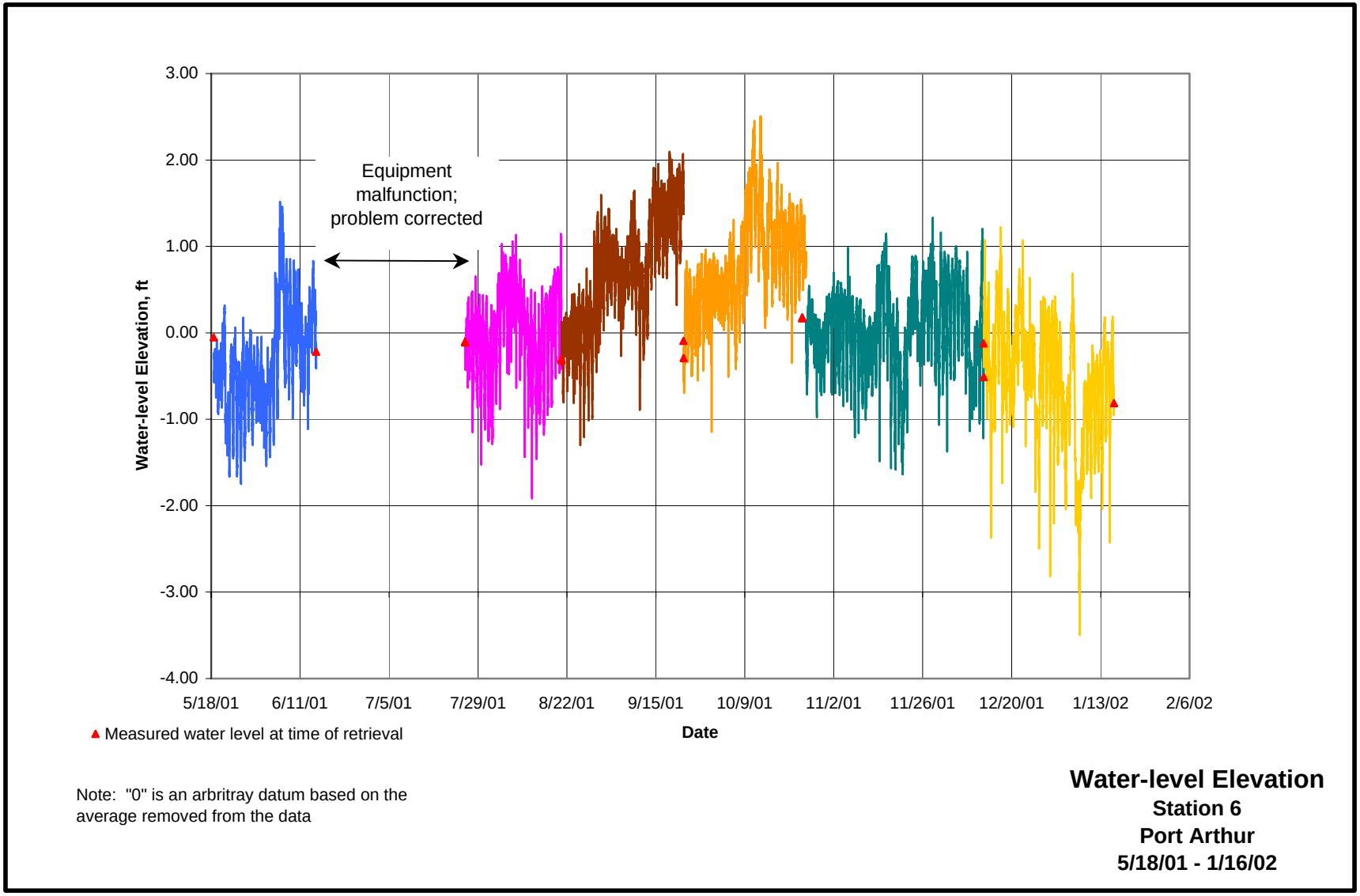

Figure 26. Water-level elevation record for Station 6 from 5/18/01 – 01/16/02.

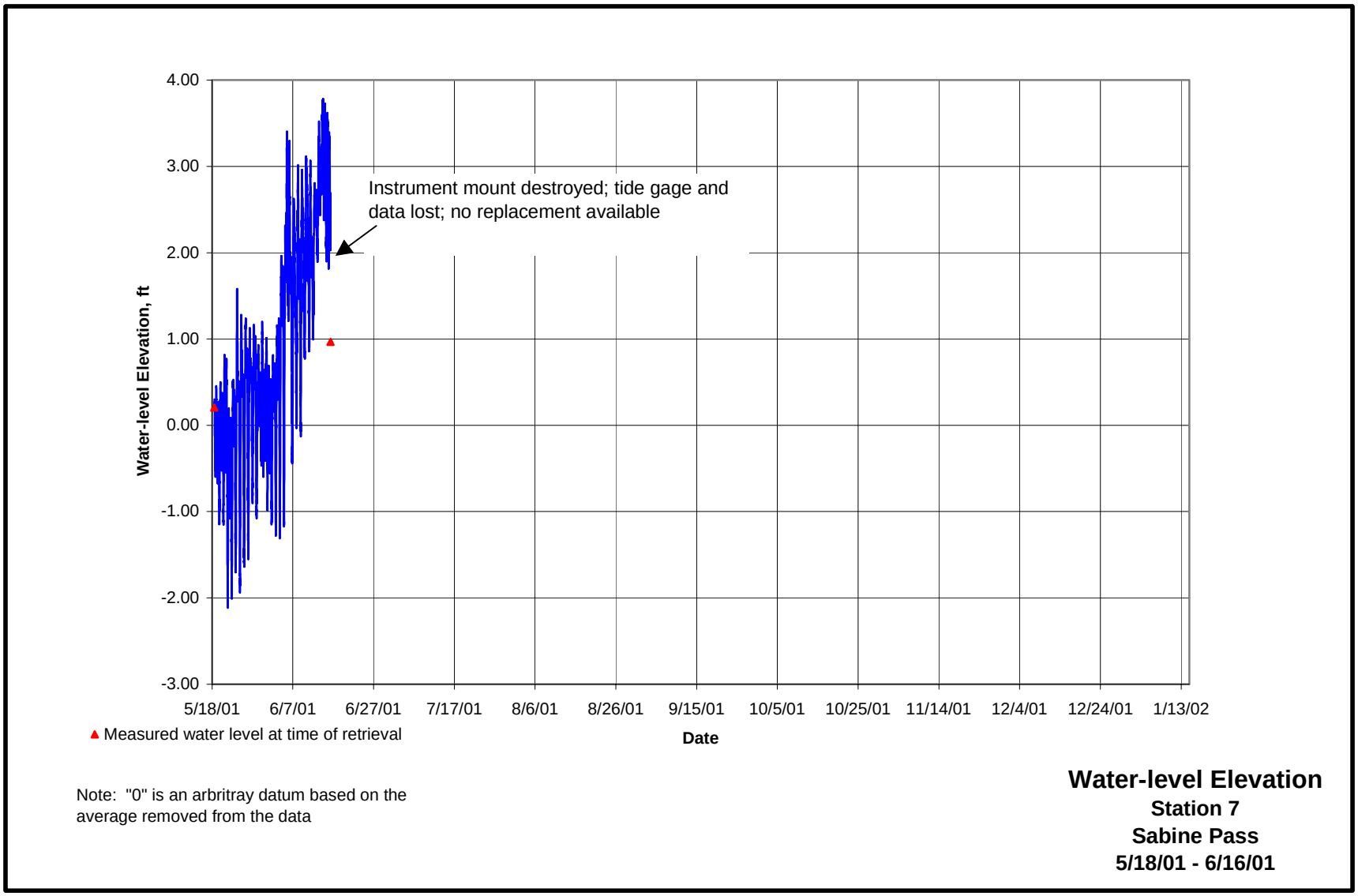

Figure 27. Water-level elevation record for Station 7 from 5/18/01 – 06/16/01.

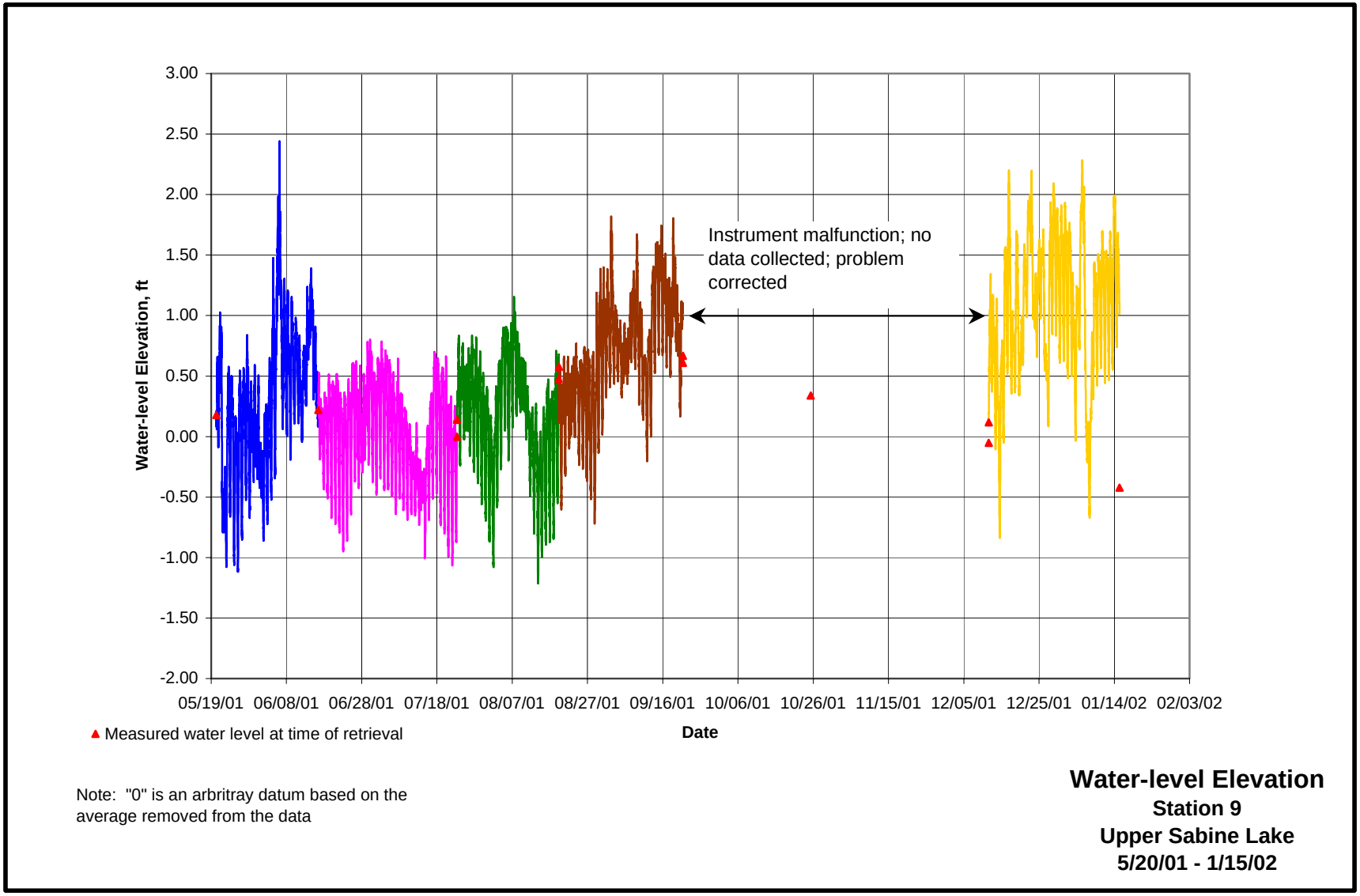

Figure 28. Water-level elevation record for Station 9 from 5/20/01 – 01/15/02.

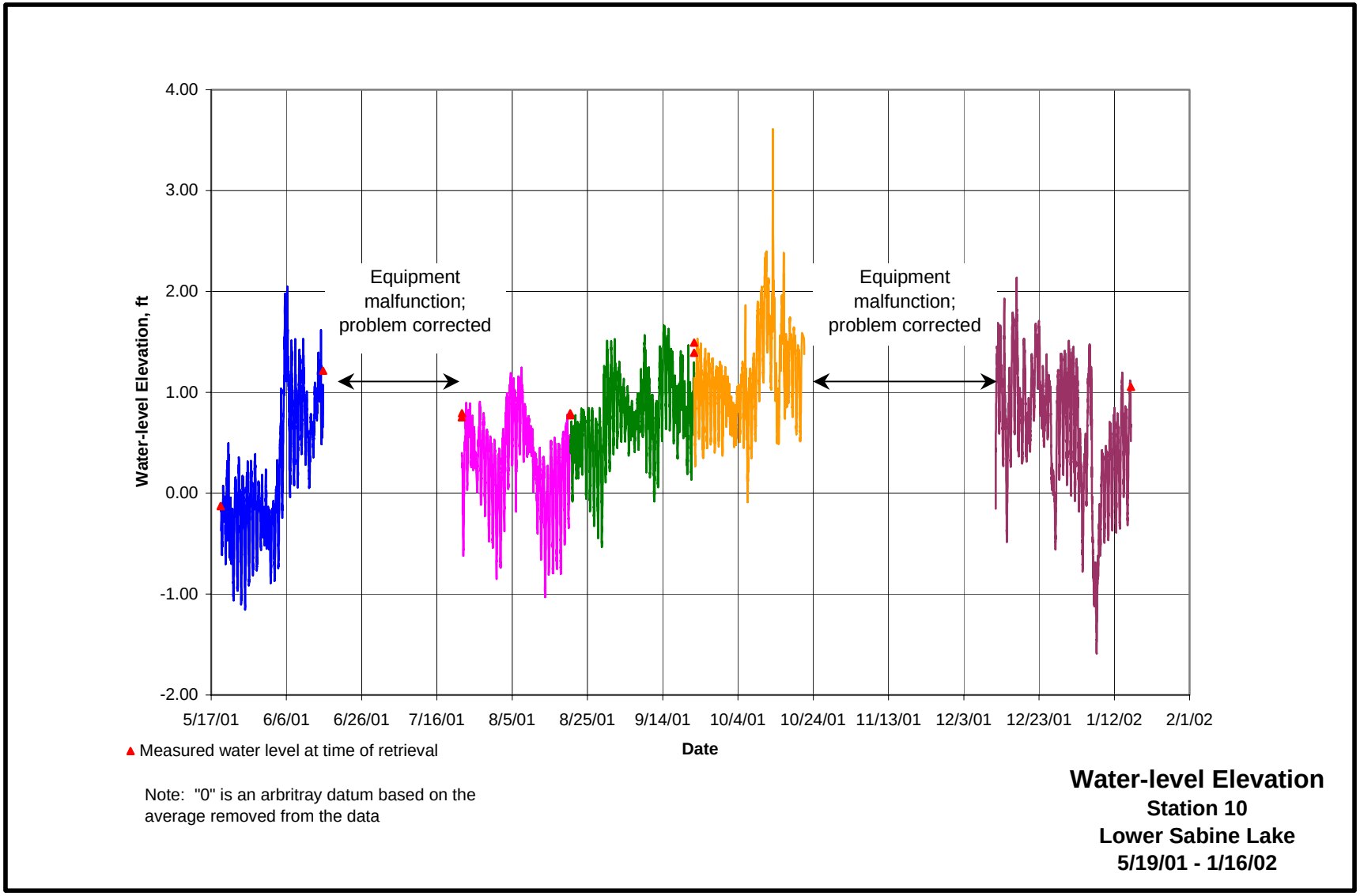

Figure 29. Water-level elevation record for Station 10 from 5/19/01 – 01/16/02.

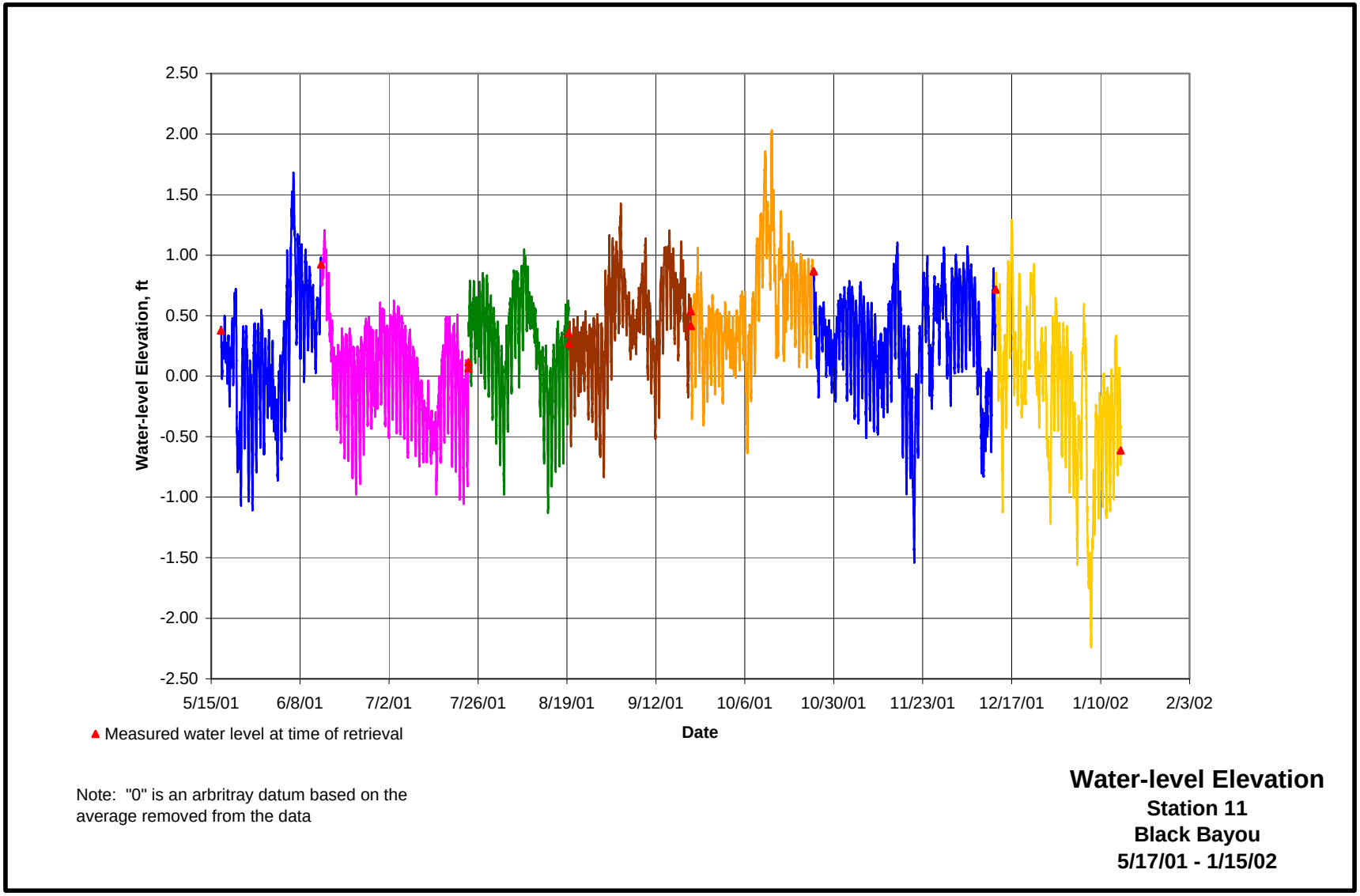

Figure 30. Water-level elevation record for Station 11 from 5/17/01 – 01/15/02.

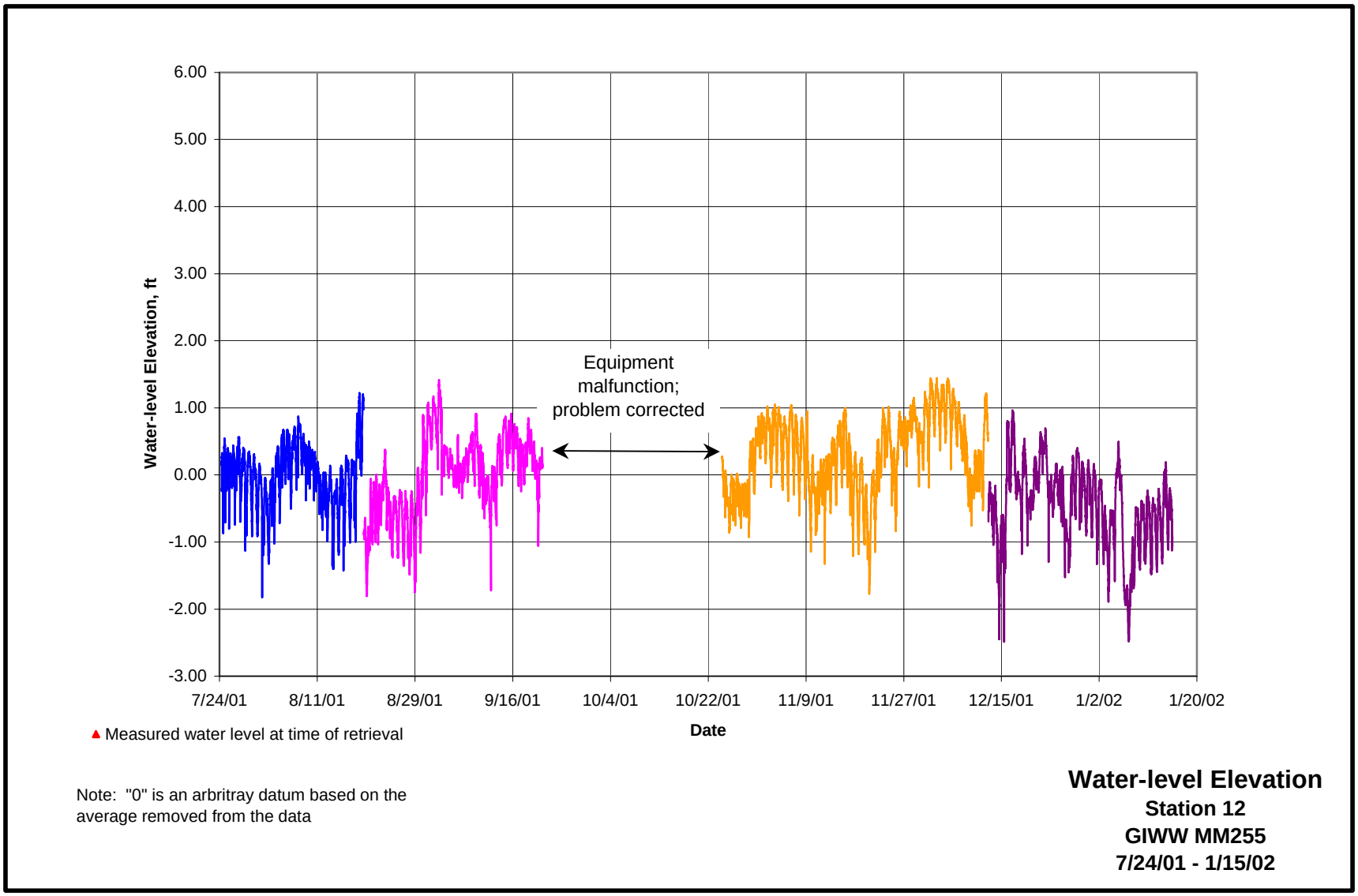

Figure 31. Water-level elevation record for Station 12 from 7/24/01 – 01/15/02.

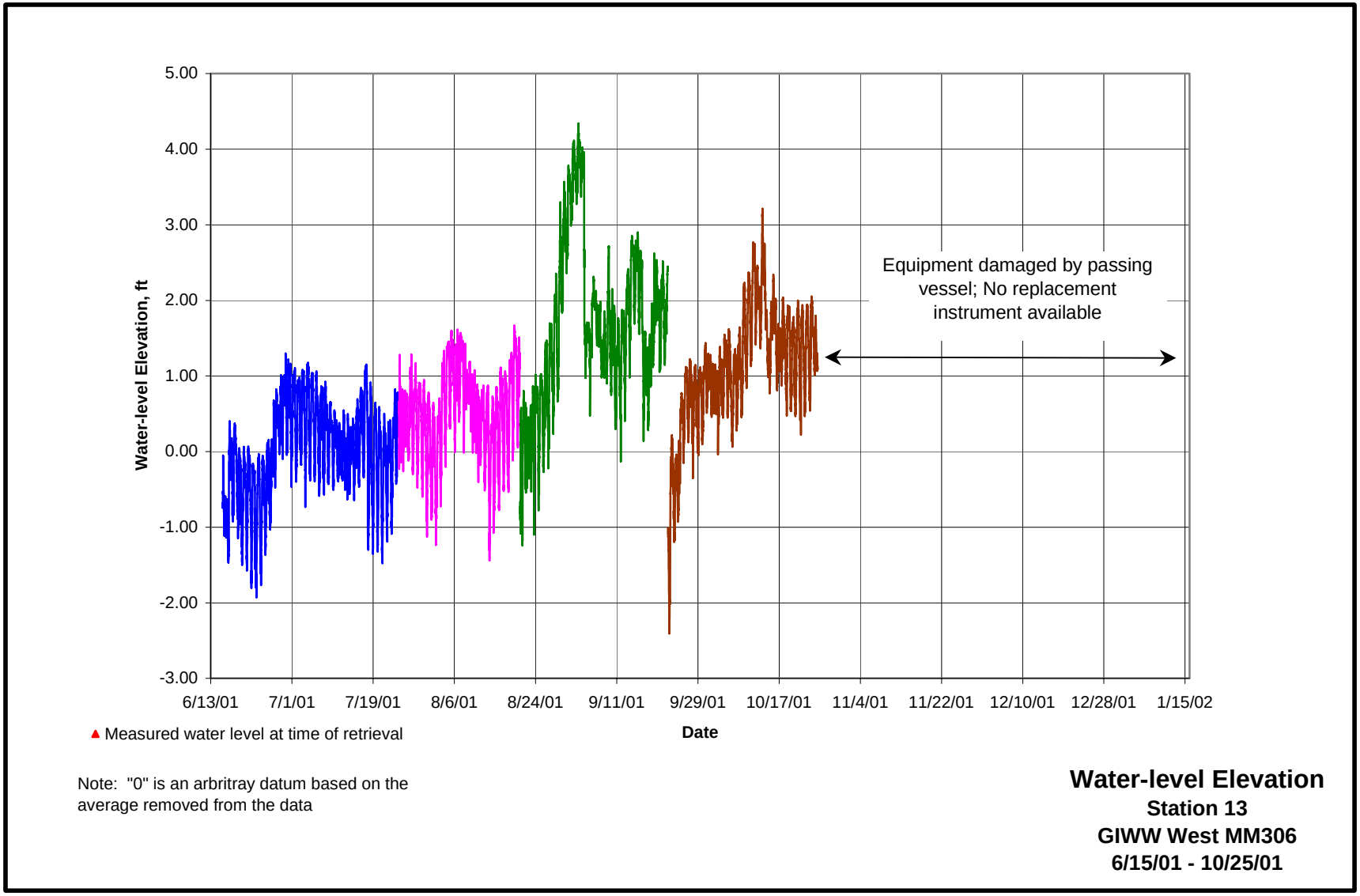

Figure 32. Water-level elevation record for Station 13 from 6/15/01 – 10/25/01.

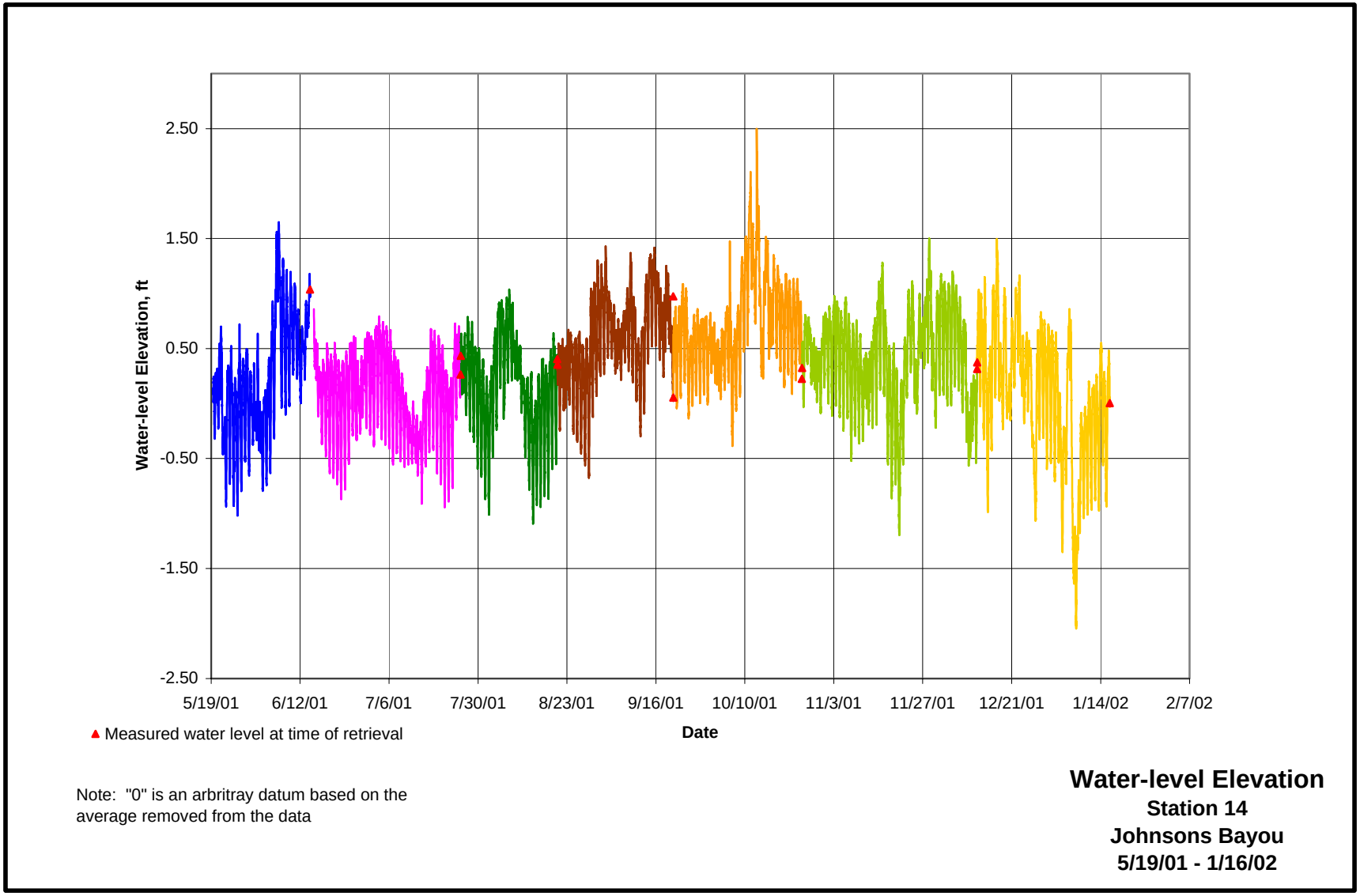

Figure 33. Water-level elevation record for Station 11 from 5/17/01 – 01/15/02.

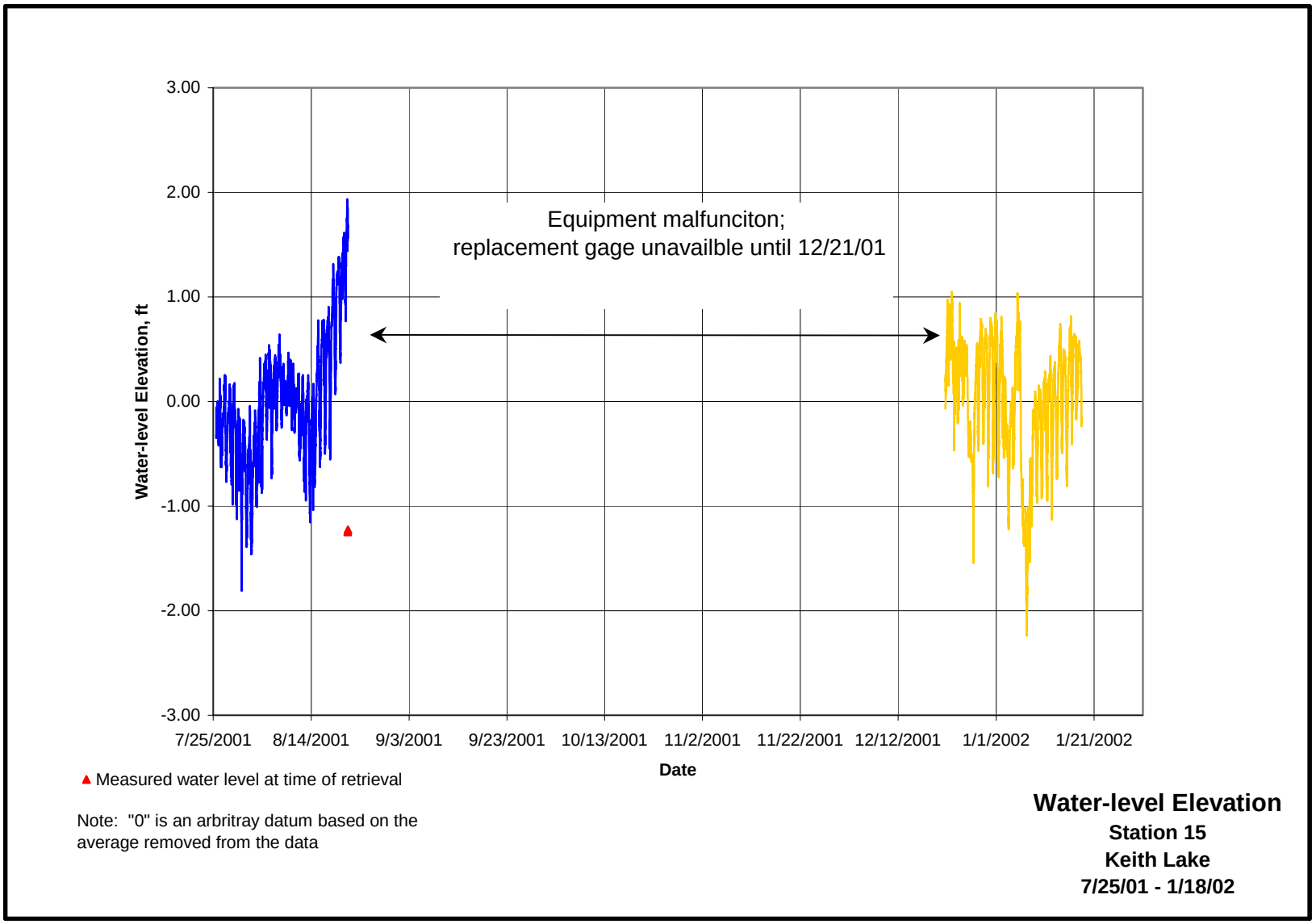

Figure 34. Water-level elevation record for Station 15 from 7/25/01 – 01/18/02.

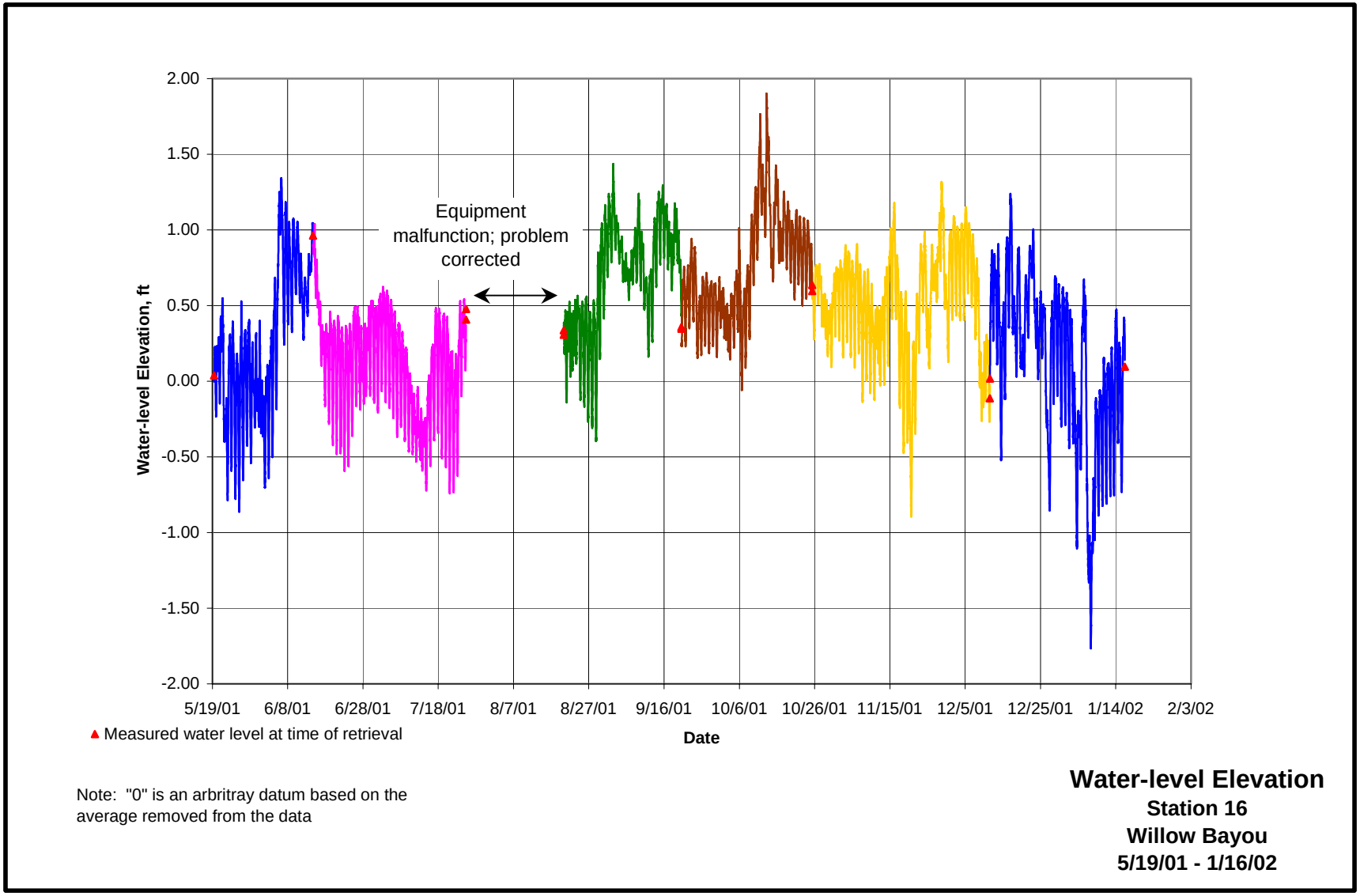

Figure 35. Water-level elevation record for Station 161 from 5/19/01 – 01/16/02.

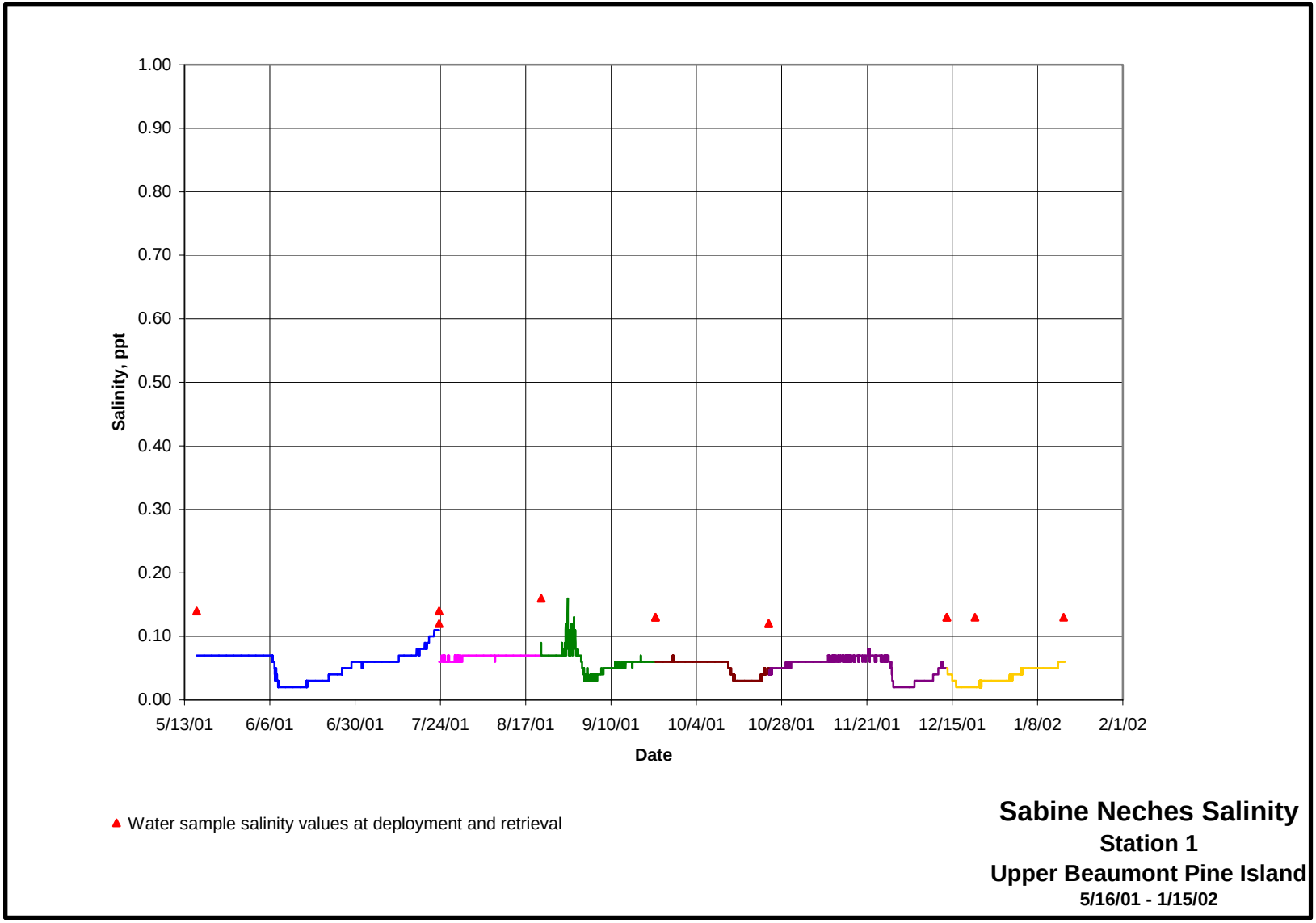

Figure 36. Salinity concentration records for Station 1 from 5/16/01 – 1/15/02.

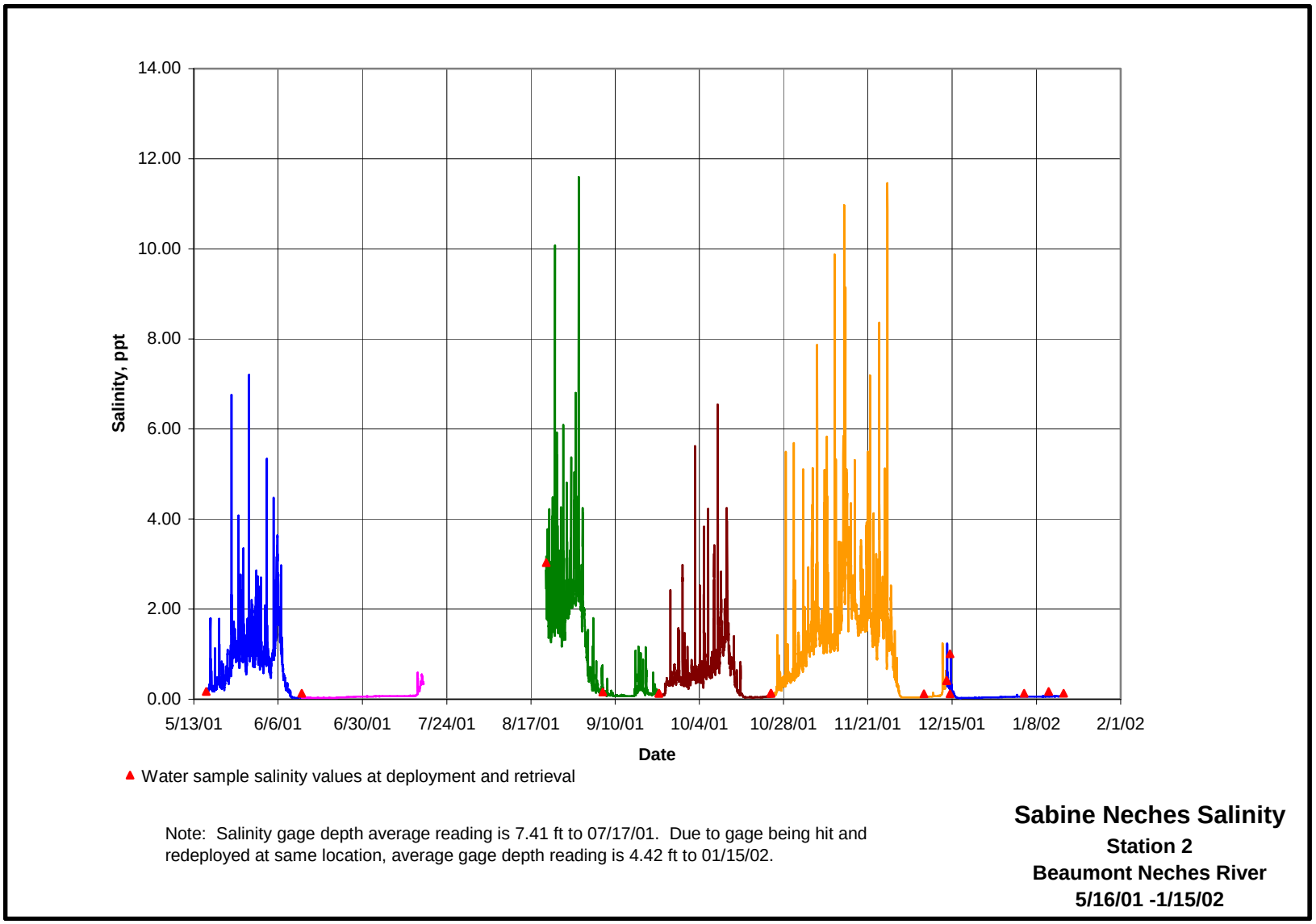

Figure 37. Salinity concentration records for Station 2 from 5/16/01 – 1/15/02.

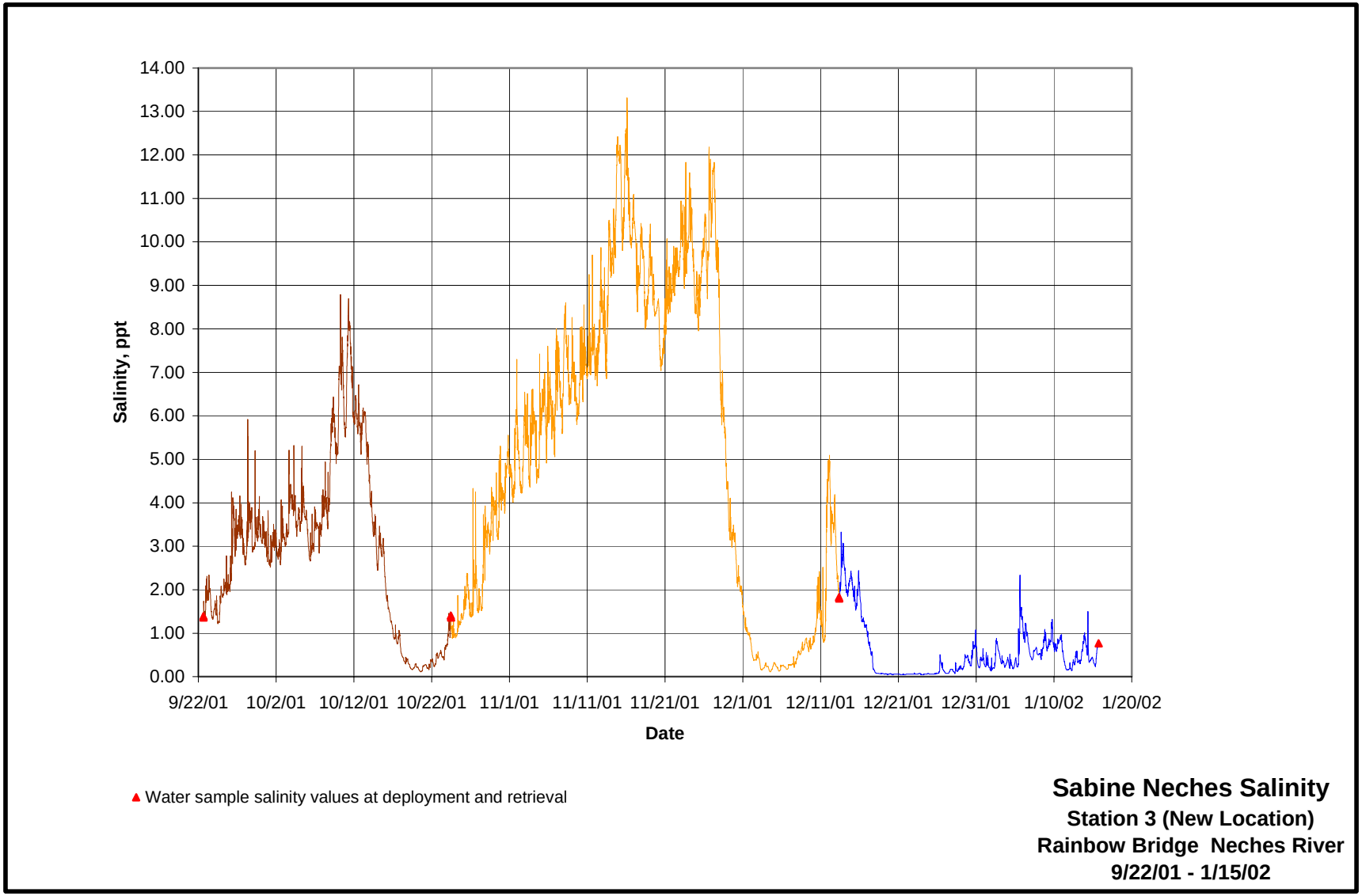

Figure 38. Salinity concentration records for Station 3 (new location; fixed depth = 10.83 ft below reference point) from 9/22/01 – 1/15/02.

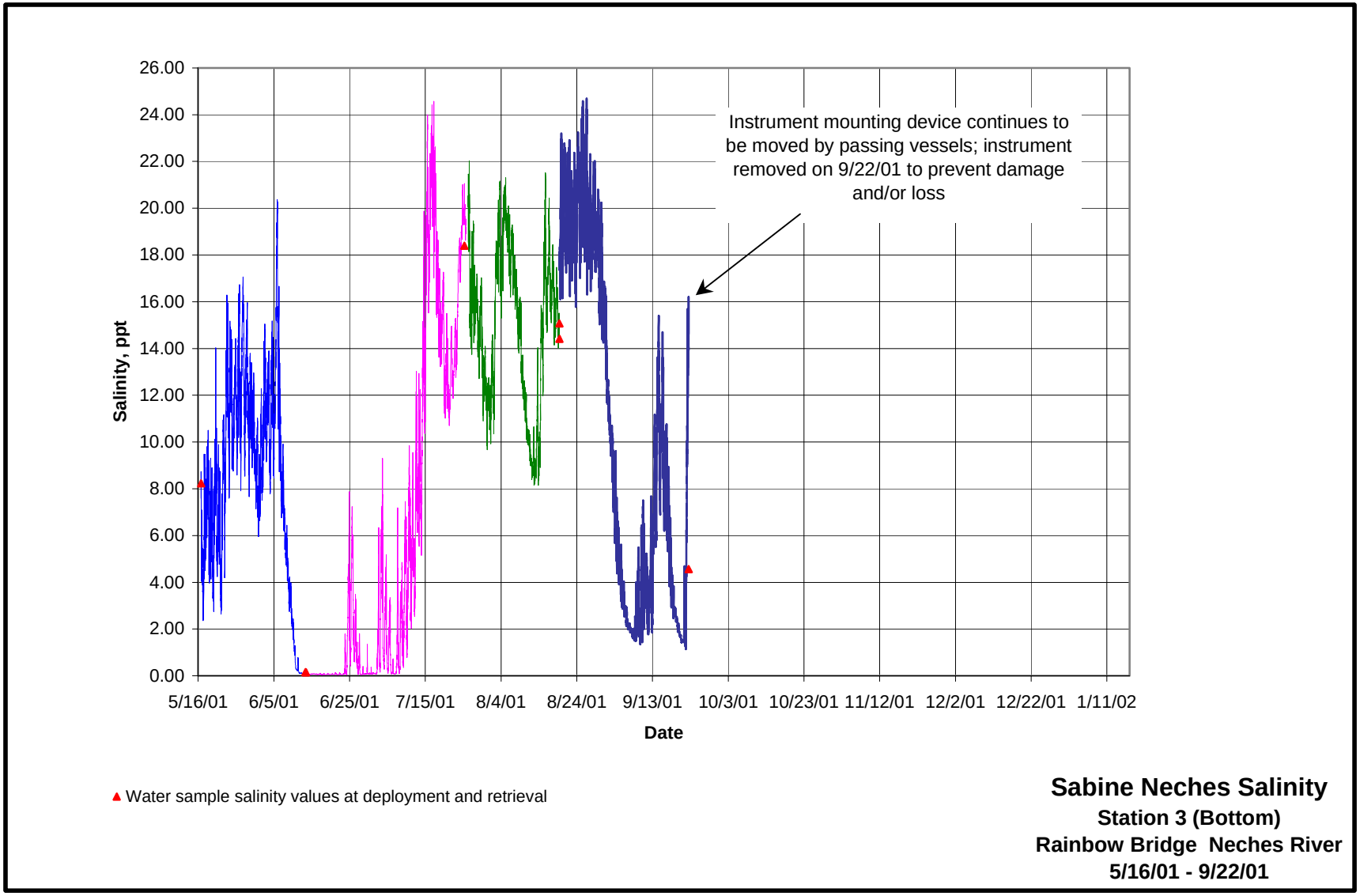

Figure 39. Salinity concentration records for Station 3 (bottom) from 5/16/01 – 9/22/01.

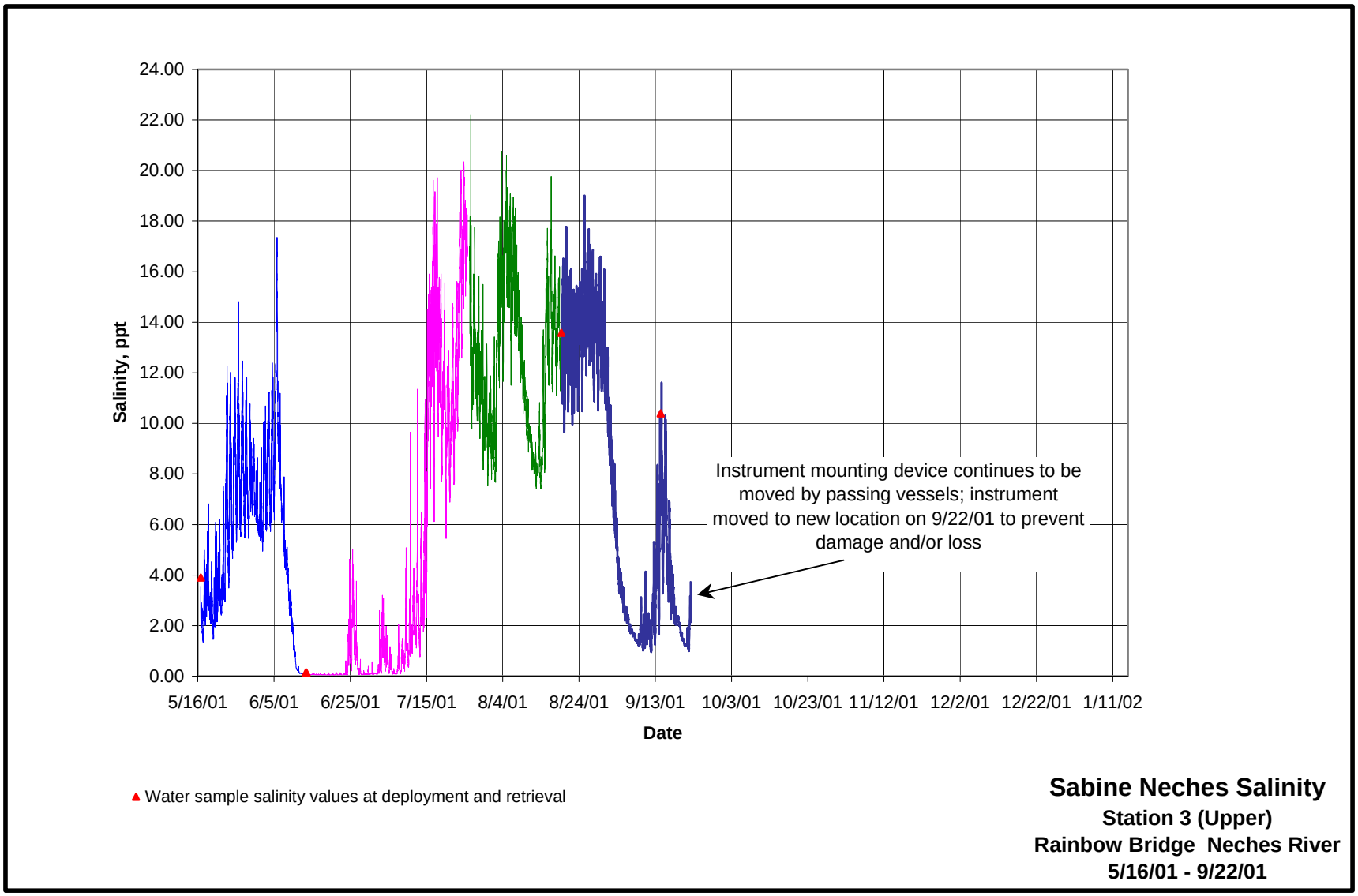

Figure 40. Salinity concentration records for Station 3 (upper) from 5/16/01 – 9/22/01.

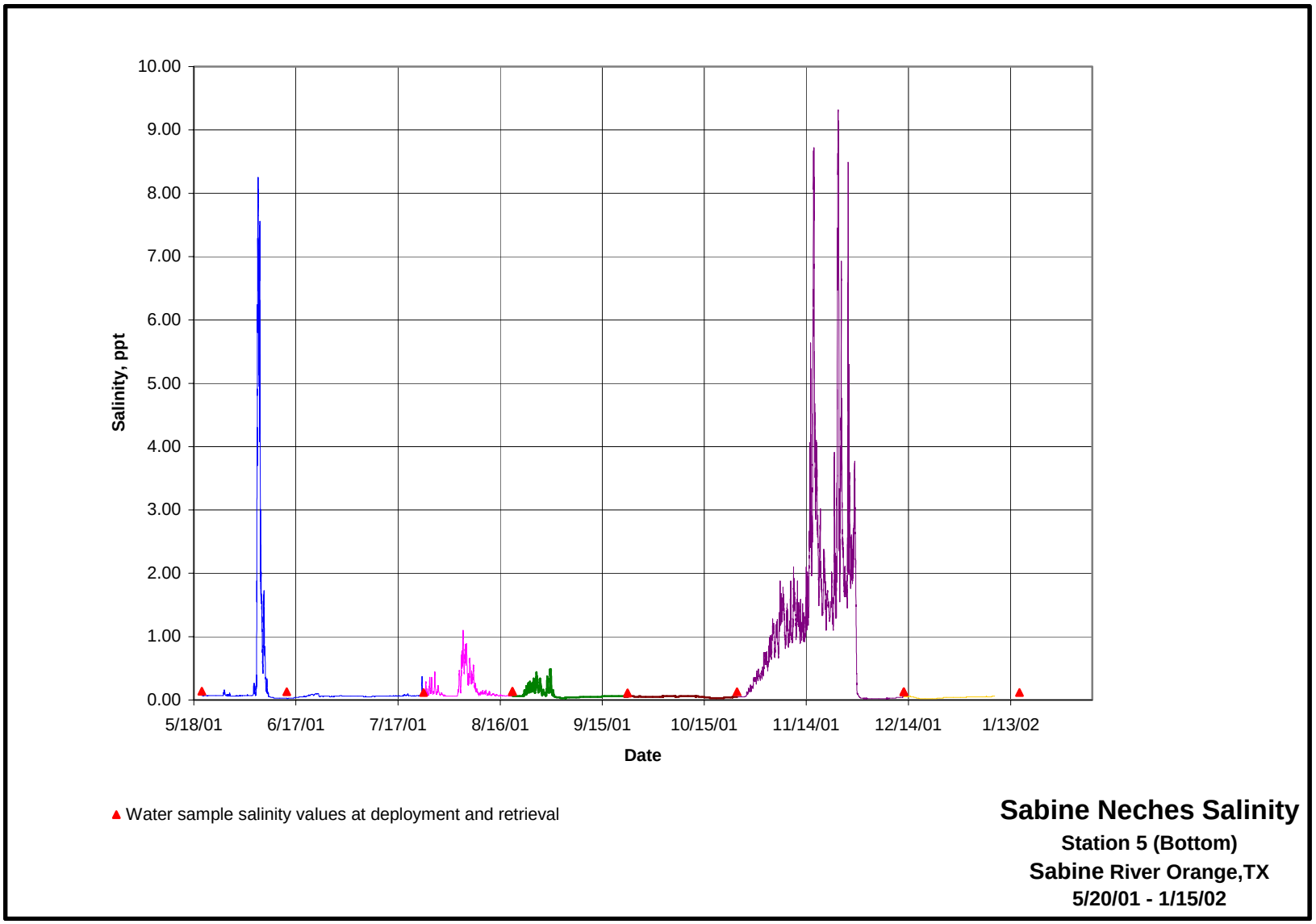

Figure 41. Salinity concentration records for Station 5 (new bottom) from 5/20/01 – 1/15/02.

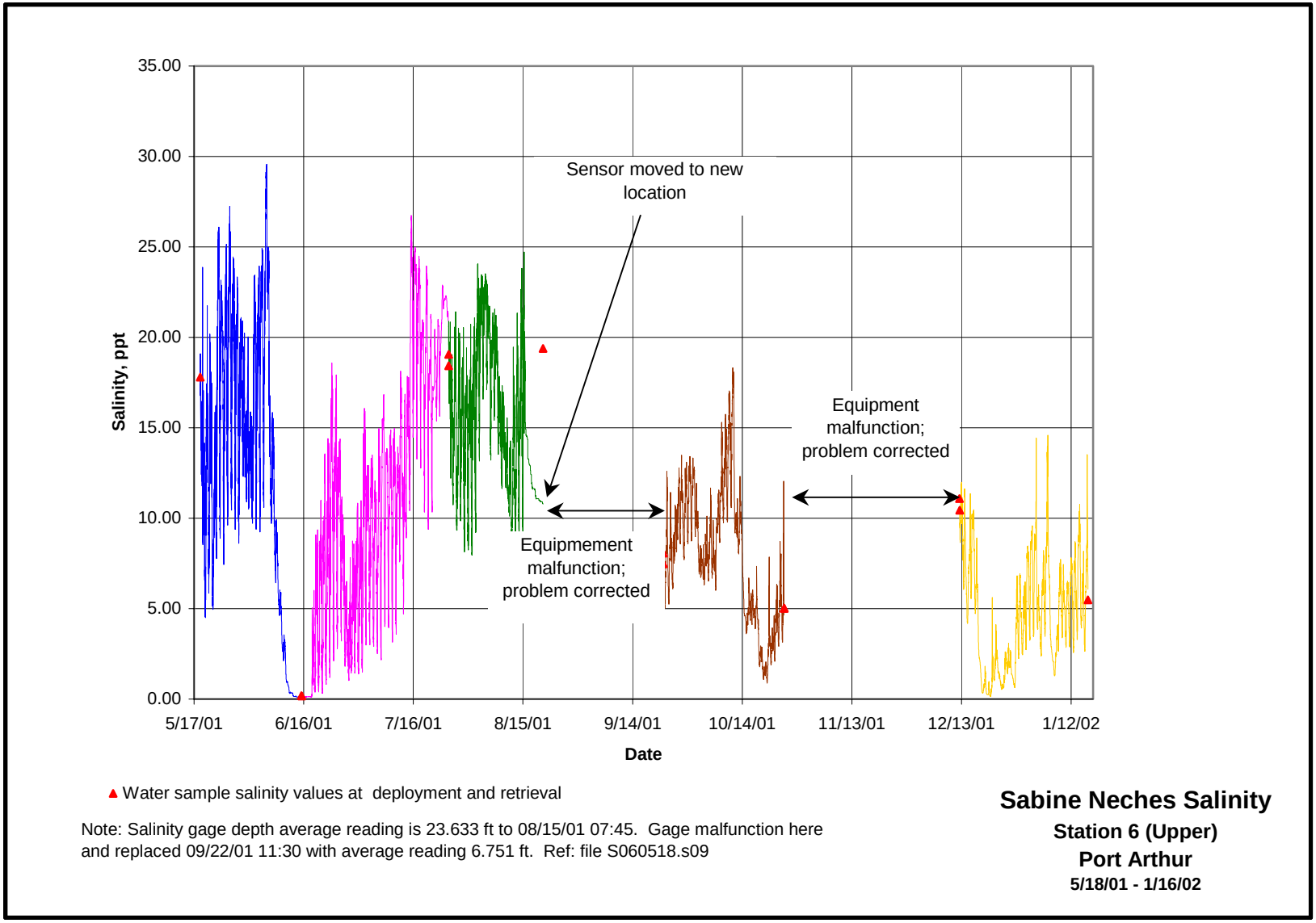

Figure 42. Salinity concentration records for Station 6 (upper) from 5/18/01 – 1/16/02.

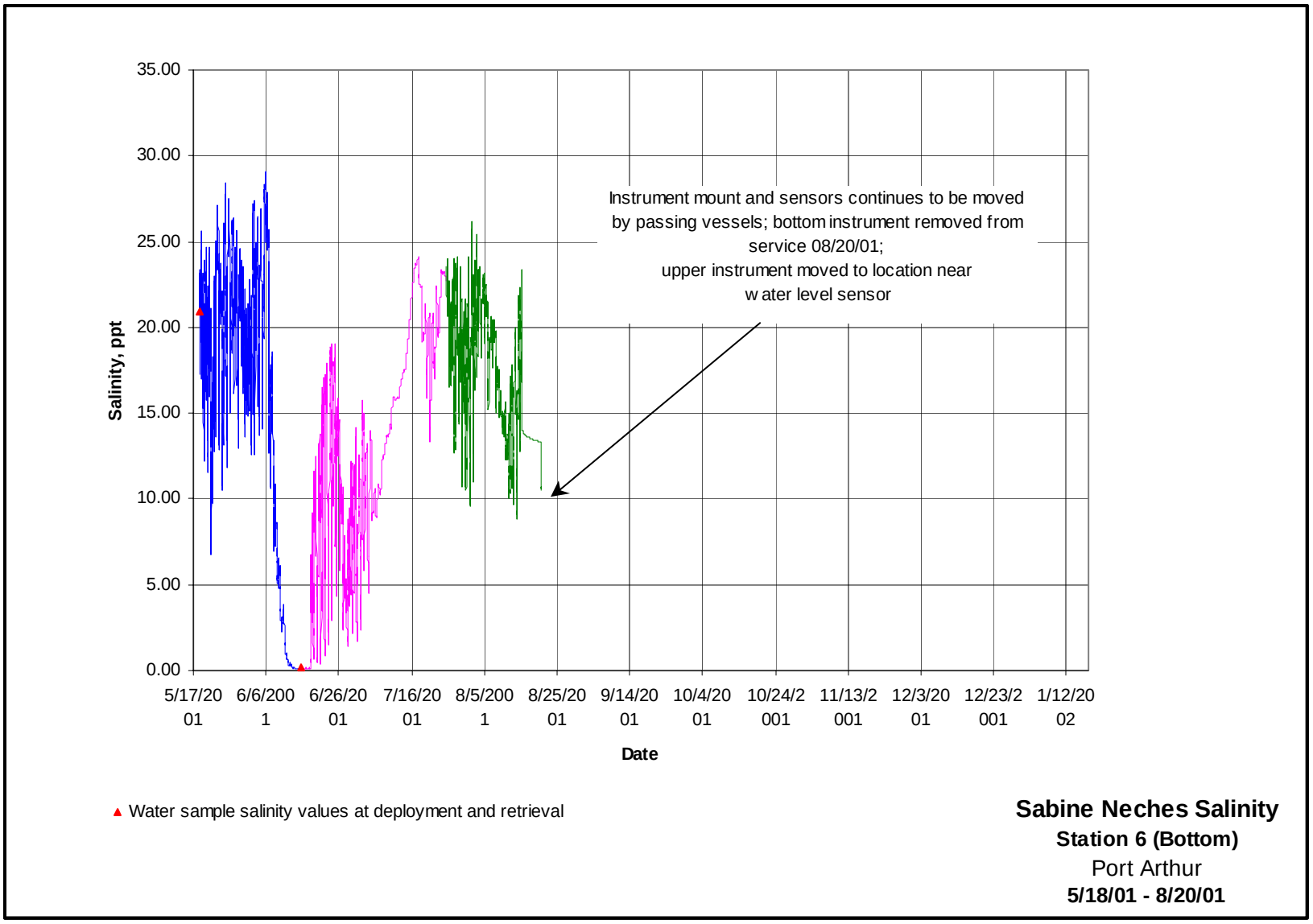

Figure 43. Salinity concentration records for Station 6 (bottom) from 5/18/01 – 8/20/01.

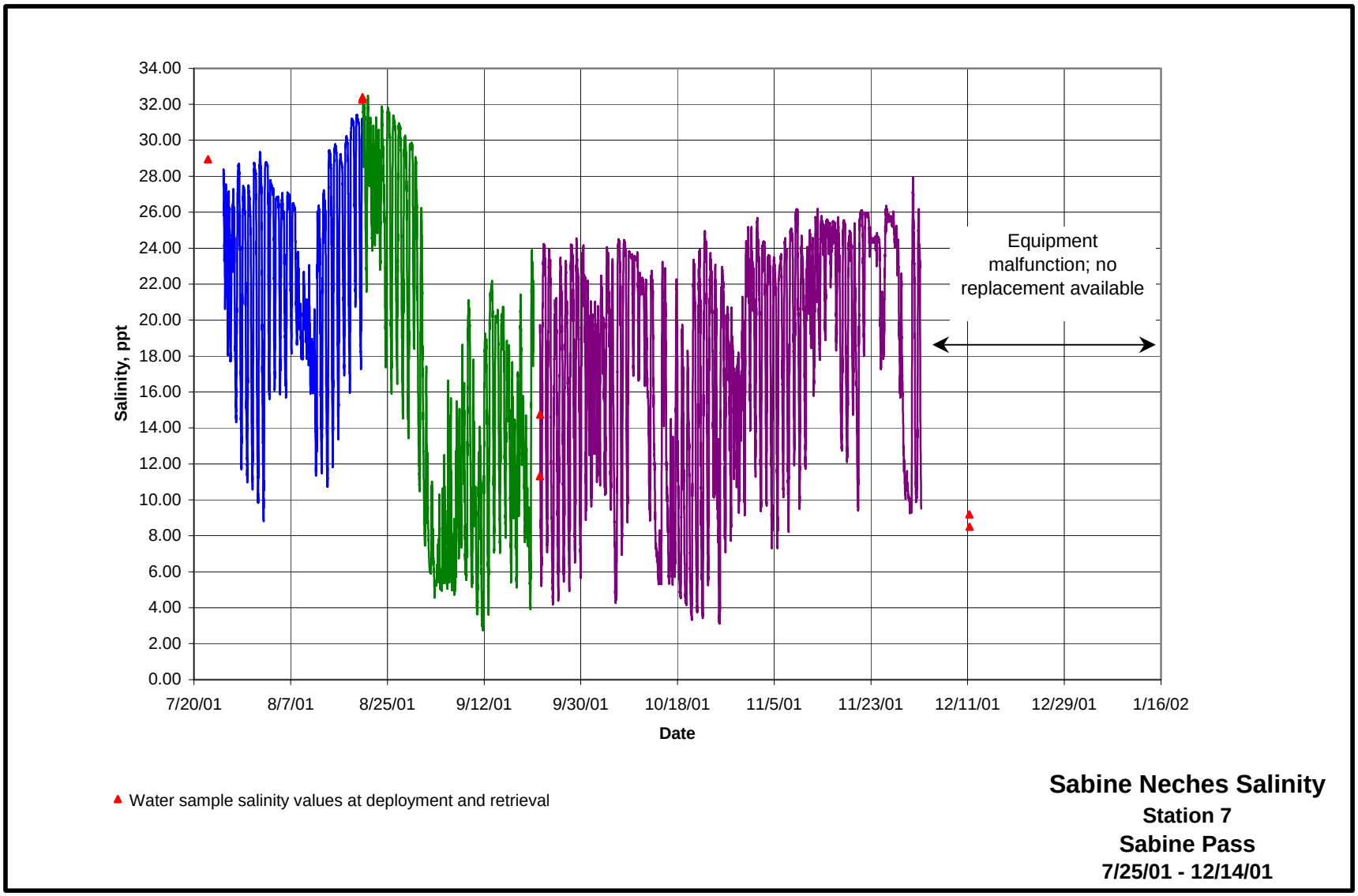

Figure 44. Salinity concentration records for Station 7 from 7/25/01 – 12/14/01.

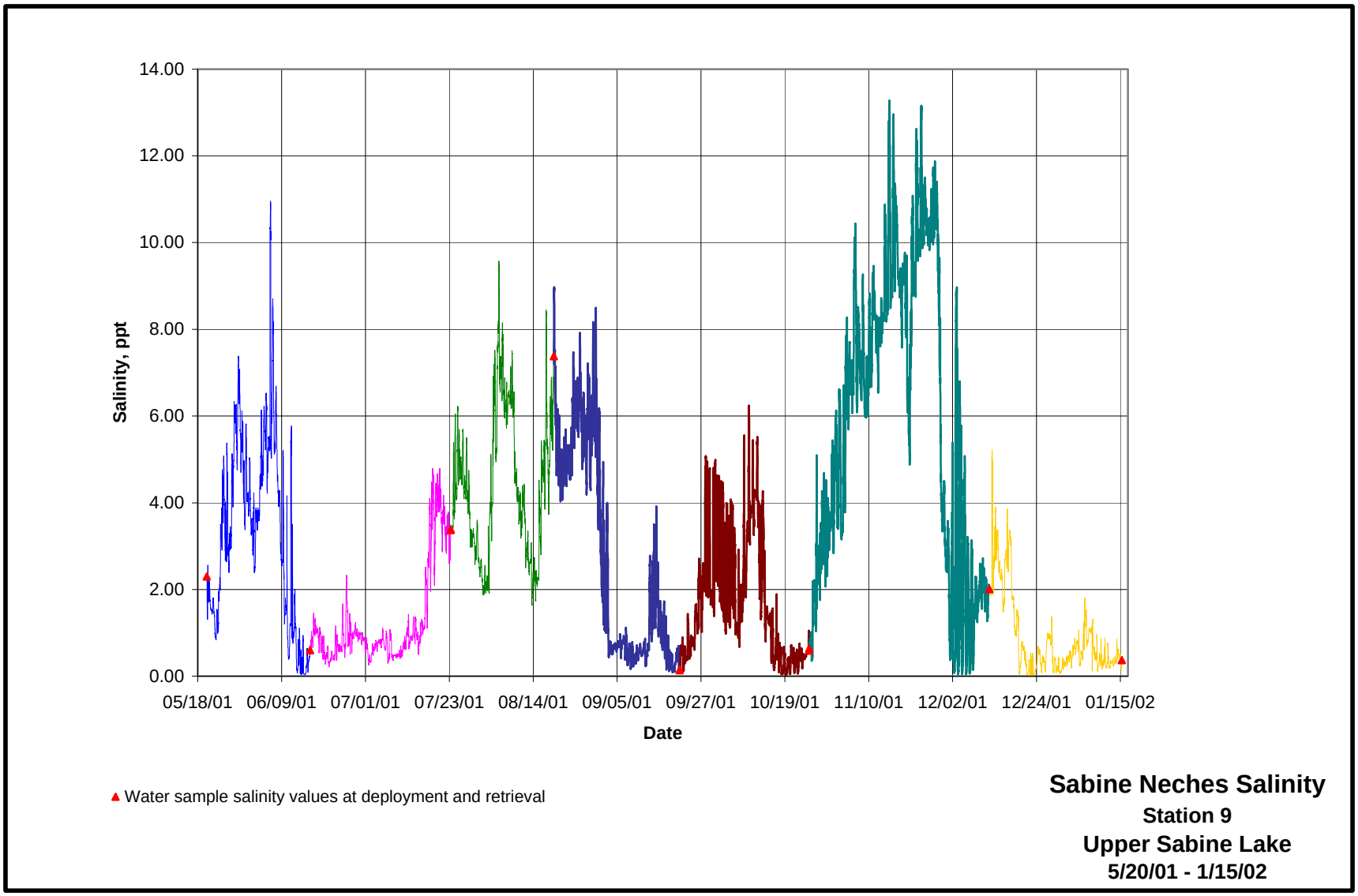

Figure 45. Salinity concentration records for Station 9 from 5/20/01 – 1/15/02.

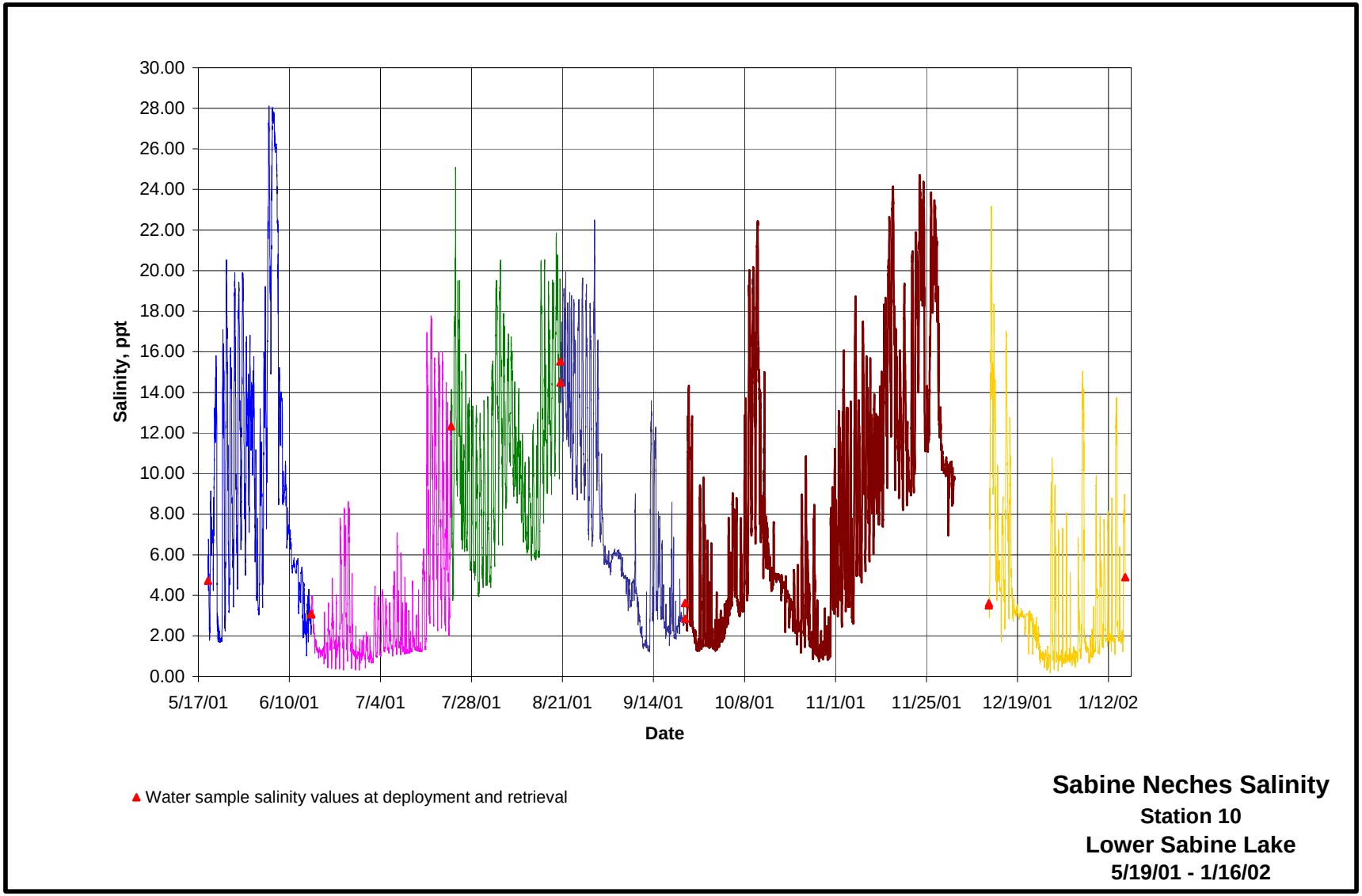

Figure 46. Salinity concentration records for Station 10 from 5/19/01 – 1/16/02.

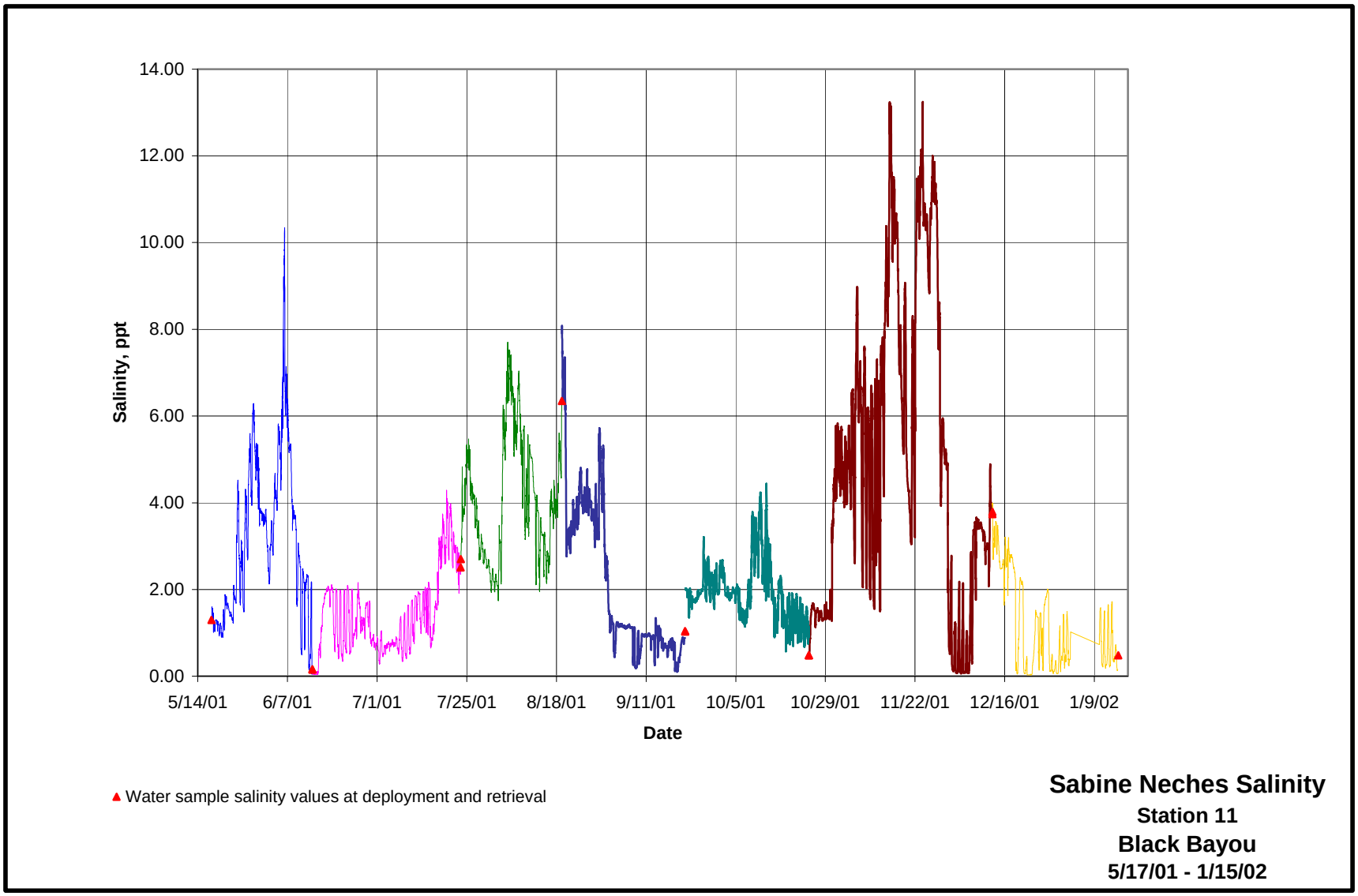

Figure 47. Salinity concentration records for Station 11 from 5/17/01 – 1/15/02.

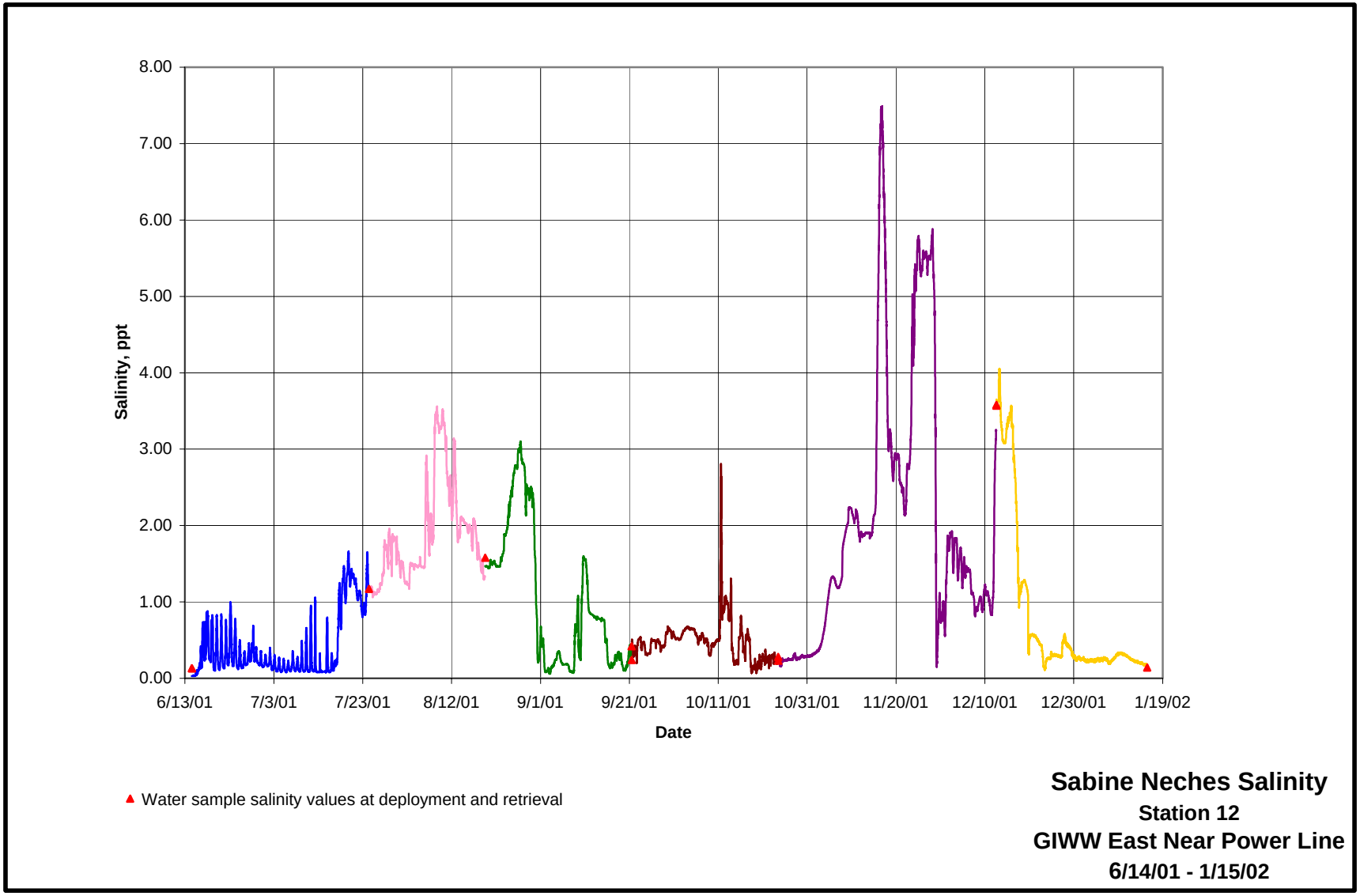

Figure 48. Salinity concentration records for Station 12 from 6/14/01 – 1/15/02.

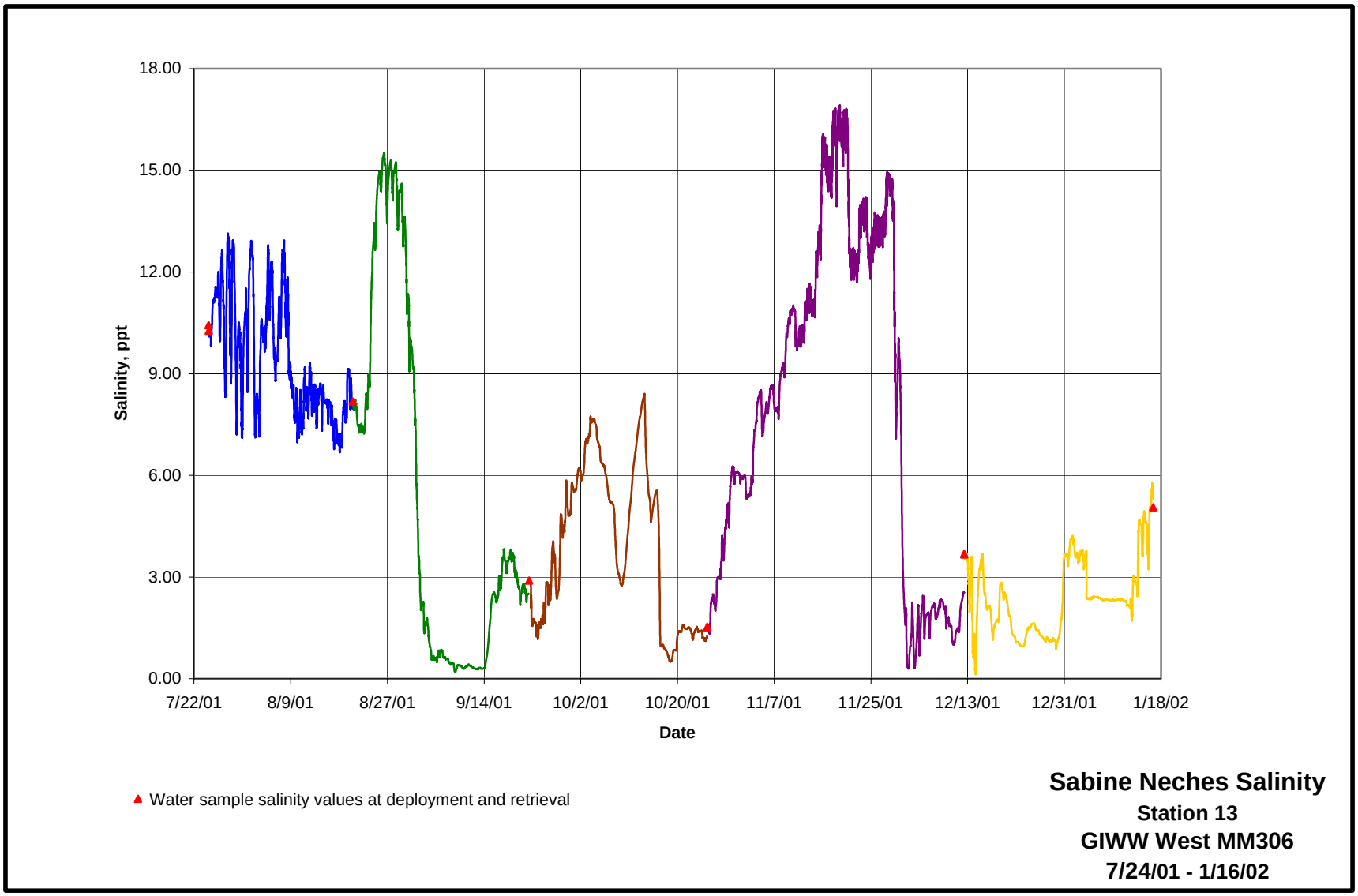

Figure 49. Salinity concentration records for Station 13 from 7/24/01 – 1/16/02.

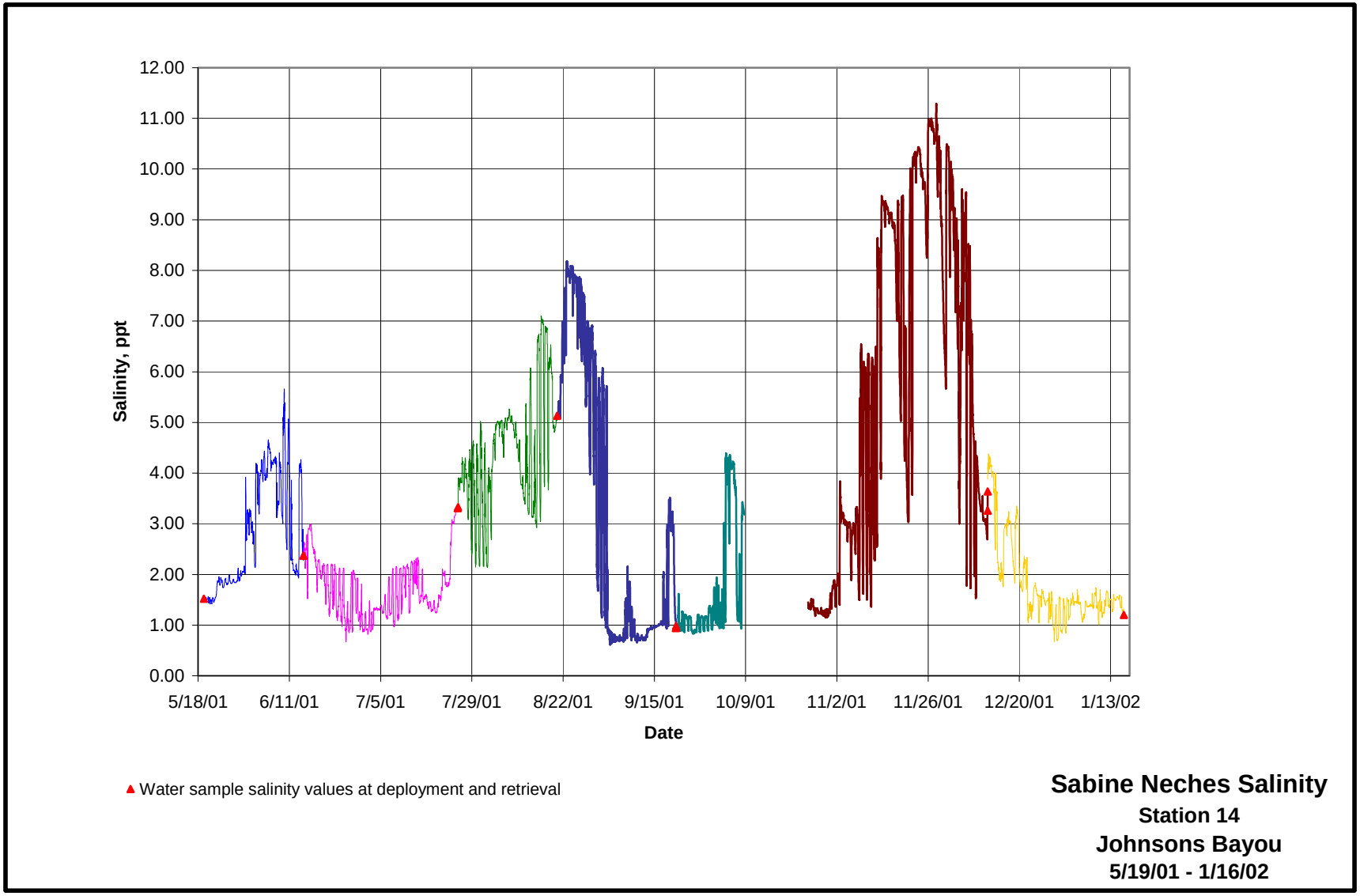

Figure 50. Salinity concentration records for Station 14 from 5/19/01 – 1/16/02.

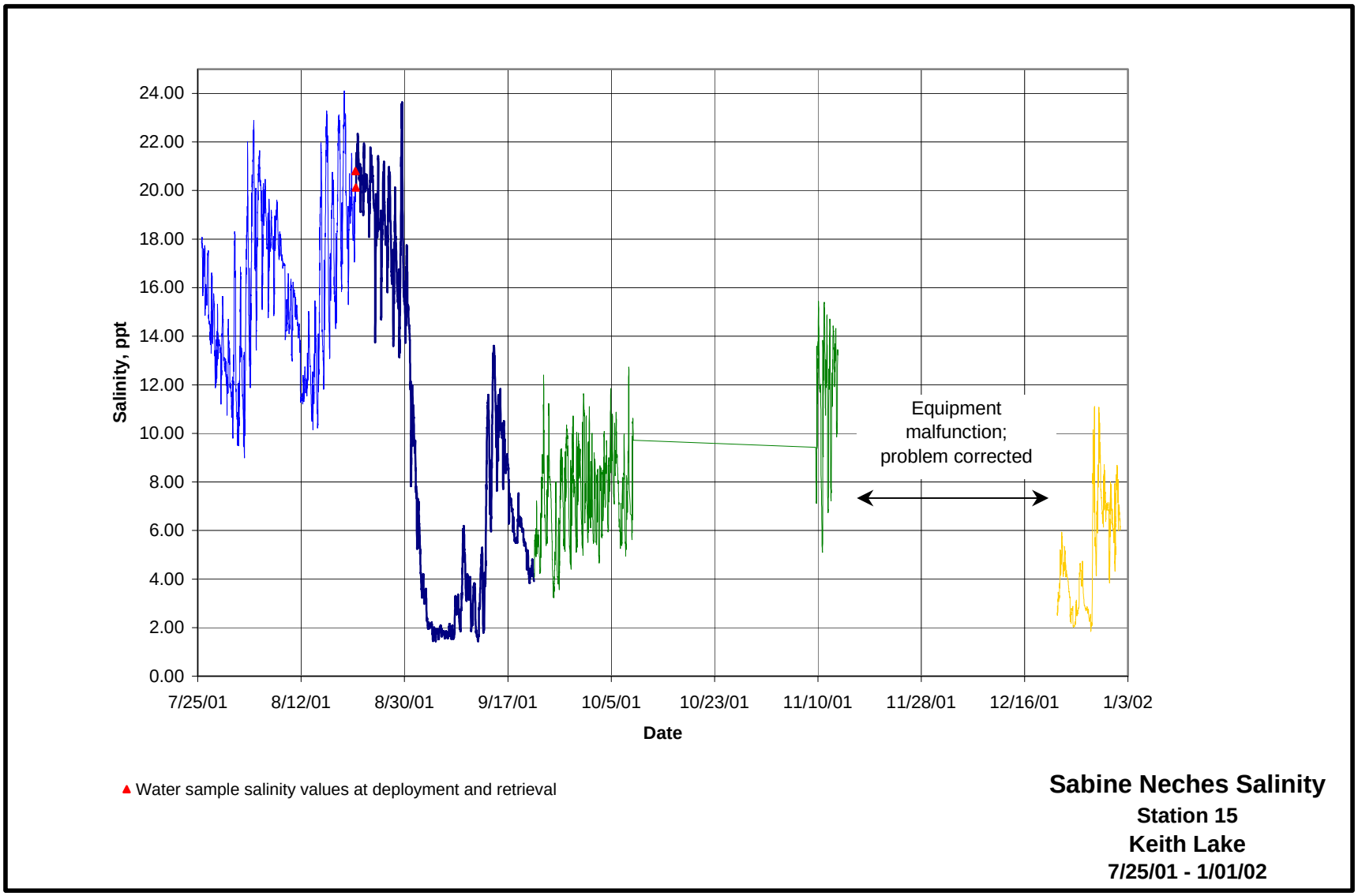

Figure 51. Salinity concentration records for Station 15 from 7/25/01 – 1/01/02.

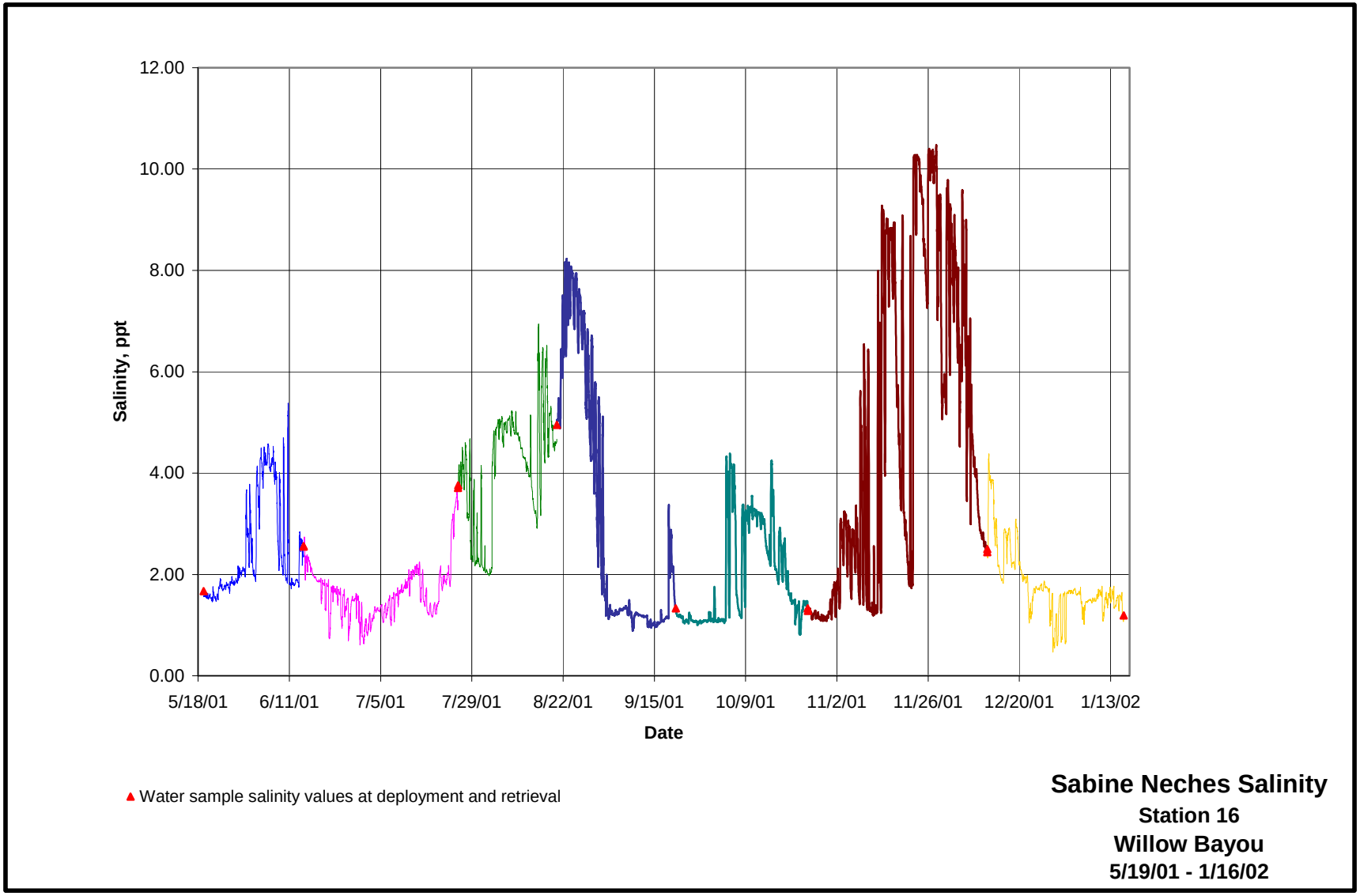

Figure 52. Salinity concentration records for Station 16 from 5/19/01 – 1/16/02.

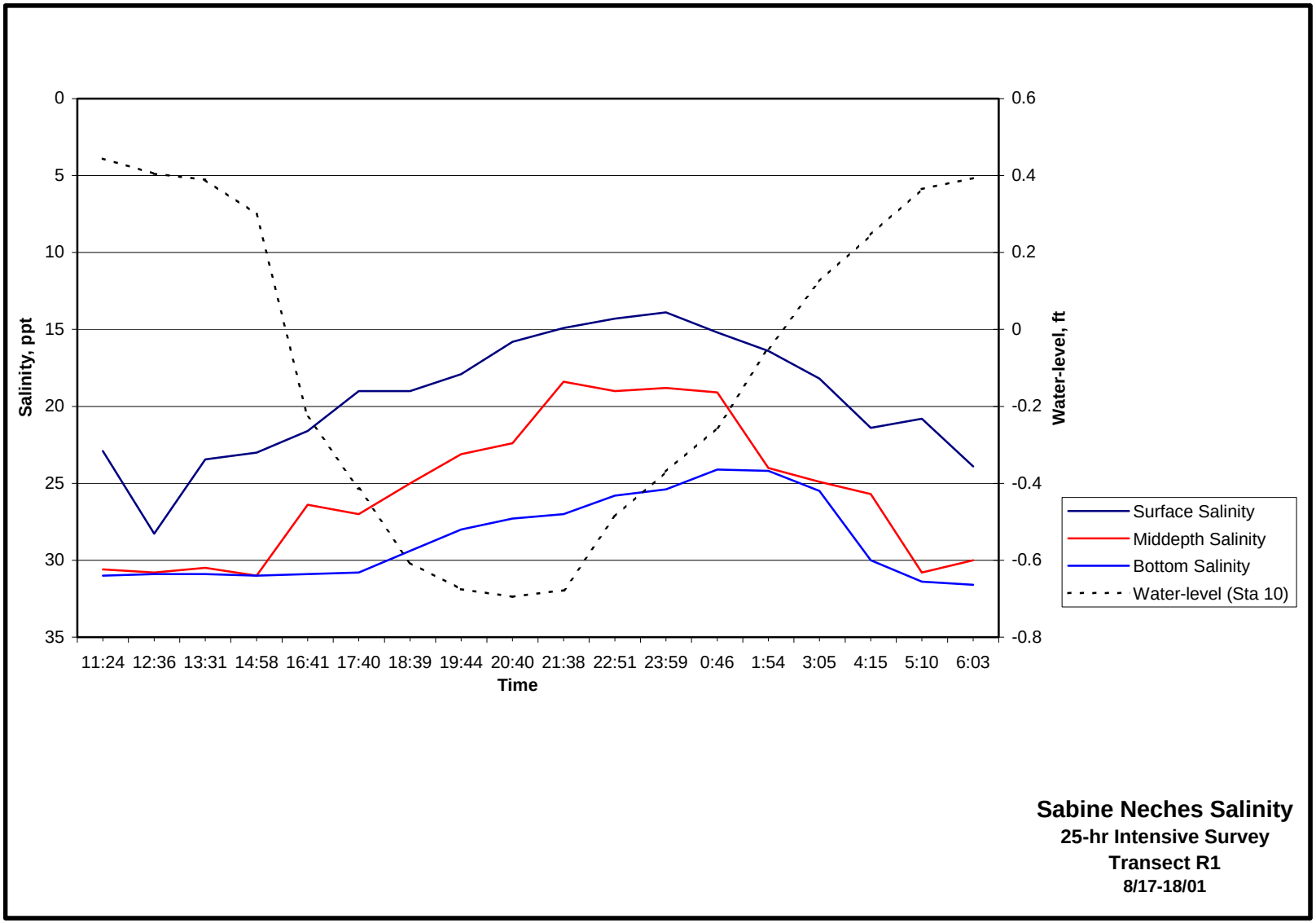

Figure 53. Salinity concentrations from water samples collected at transect R1 during 25-hr survey.

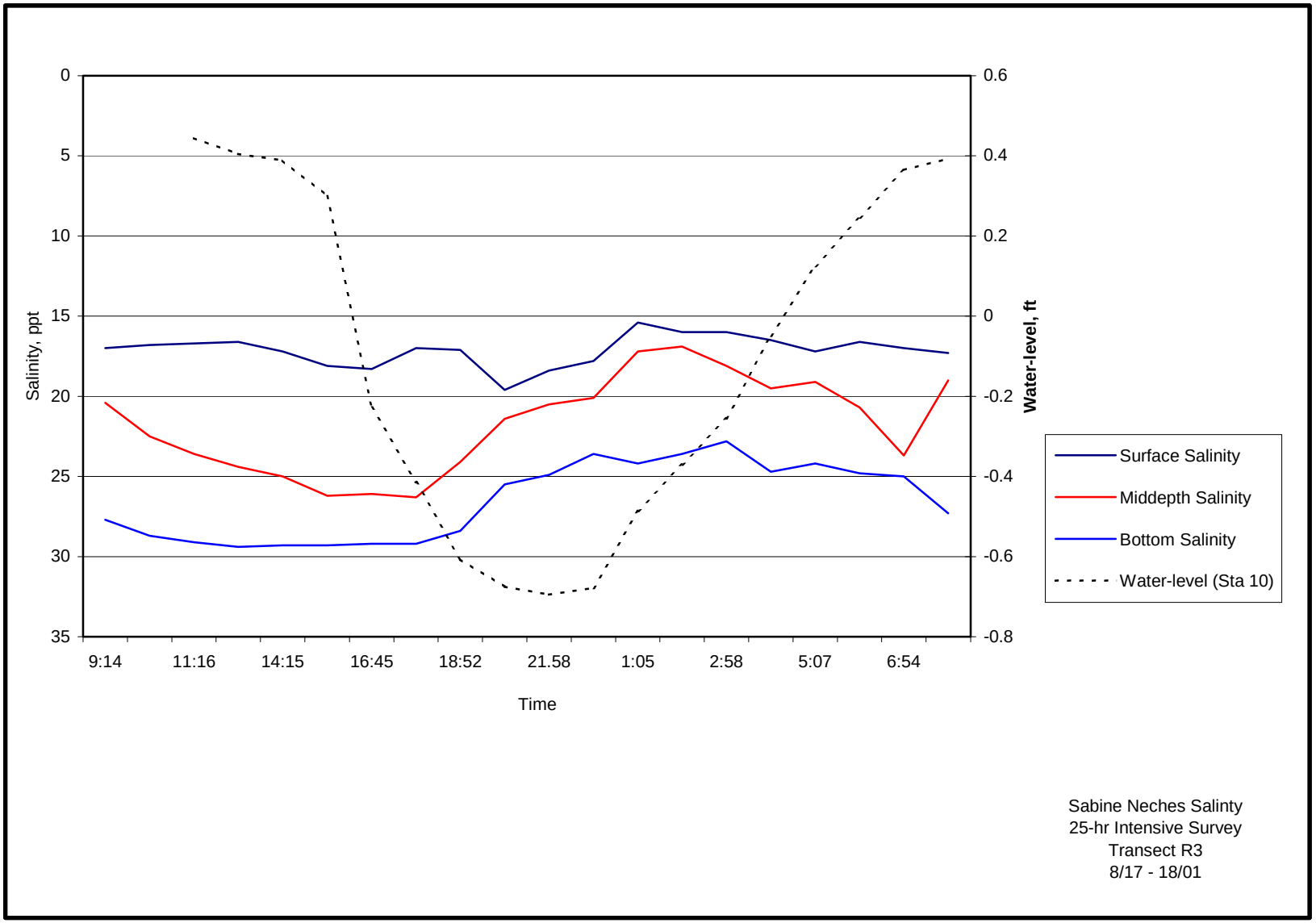

Figure 54. Salinity concentrations from water samples collected at transect R3 during 25-hr survey.

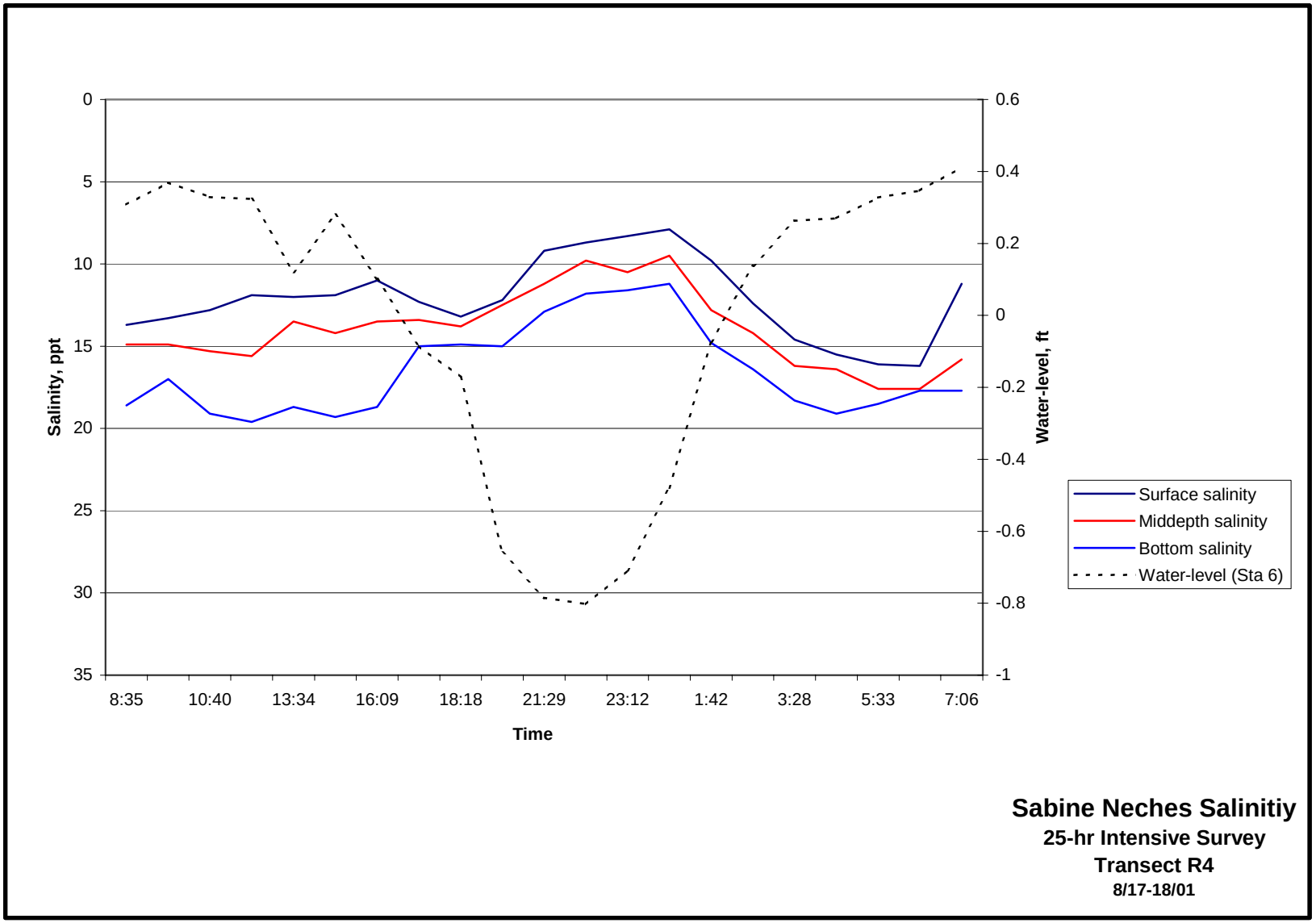

Figure 55. Salinity concentrations from water samples collected at transect R4 during 25-hr survey.

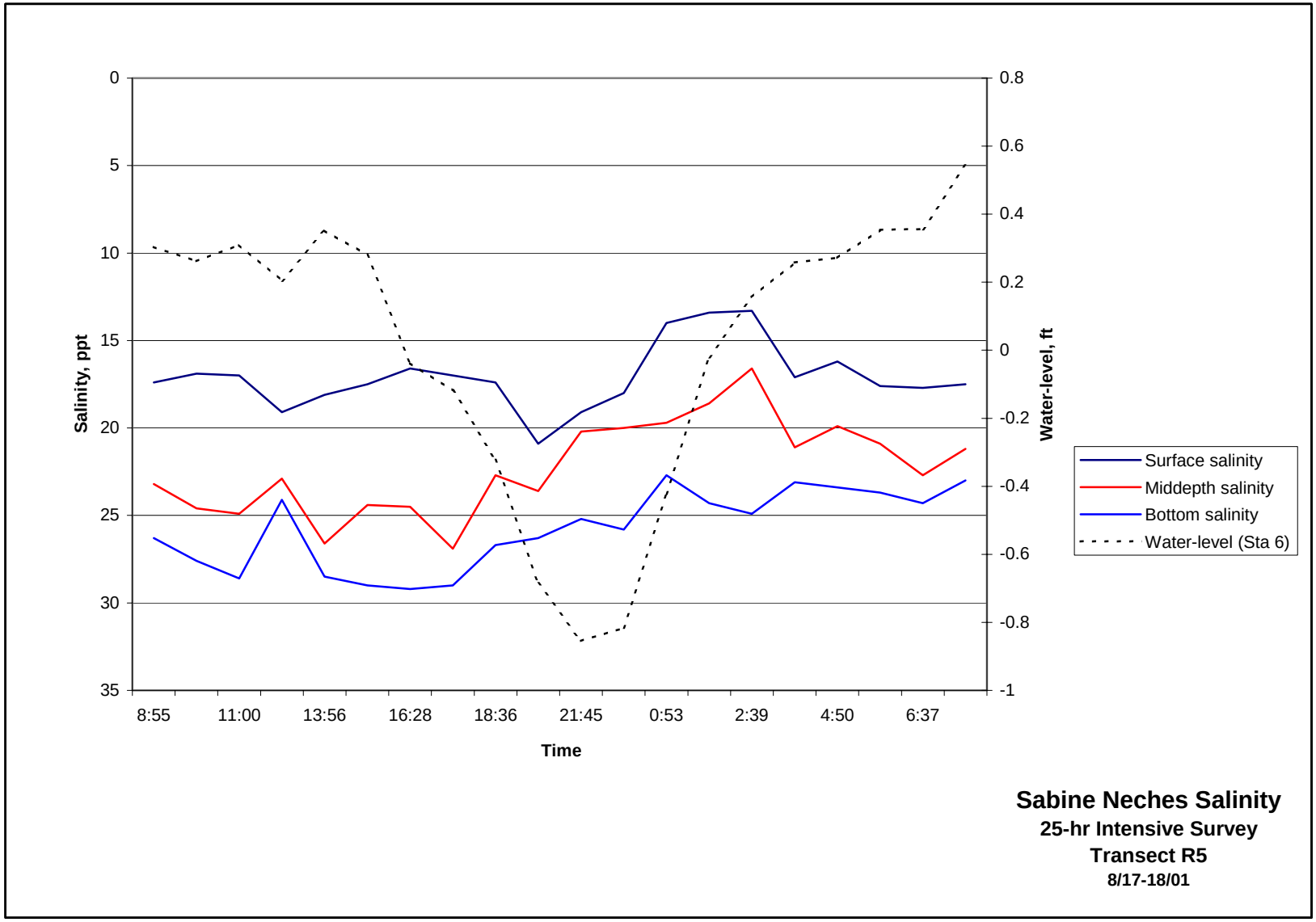

Figure 56. Salinity concentrations from water samples collected at transect R5 during 25-hr survey.

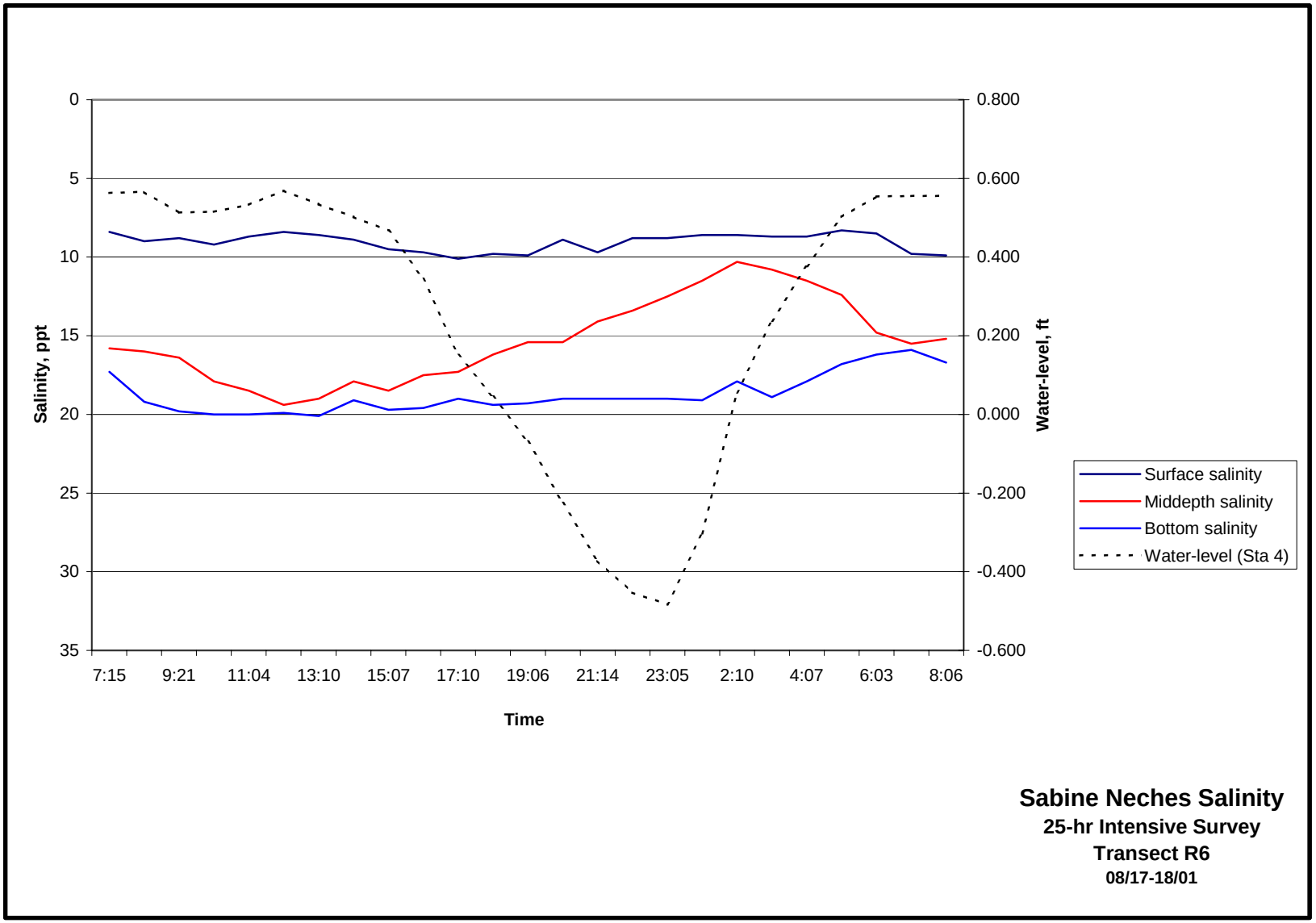

Figure 57. Salinity concentrations from water samples collected at transect R6 during 25-hr survey.

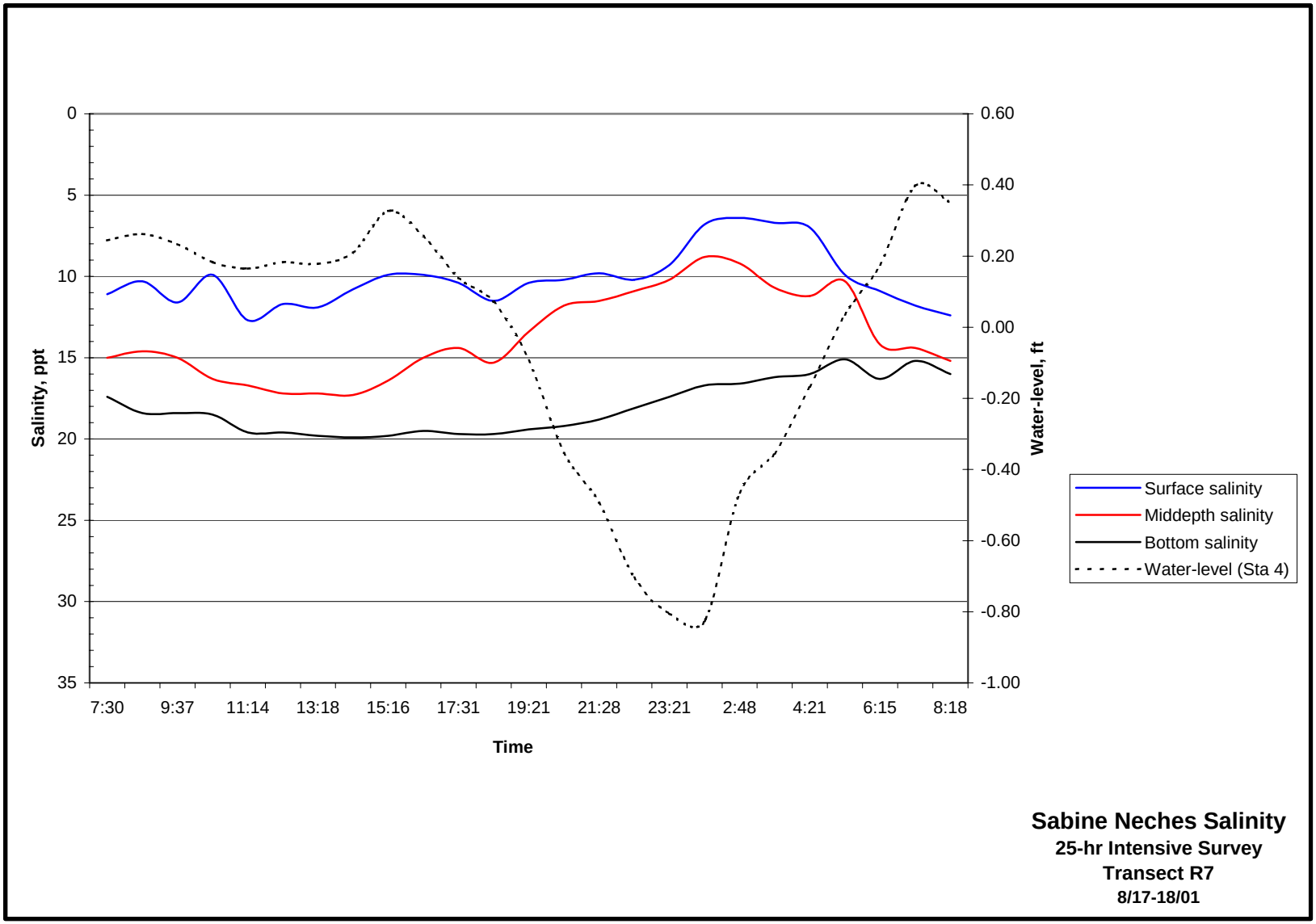

Figure 58. Salinity concentrations from water samples collected at transect R7 during 25-hr survey.

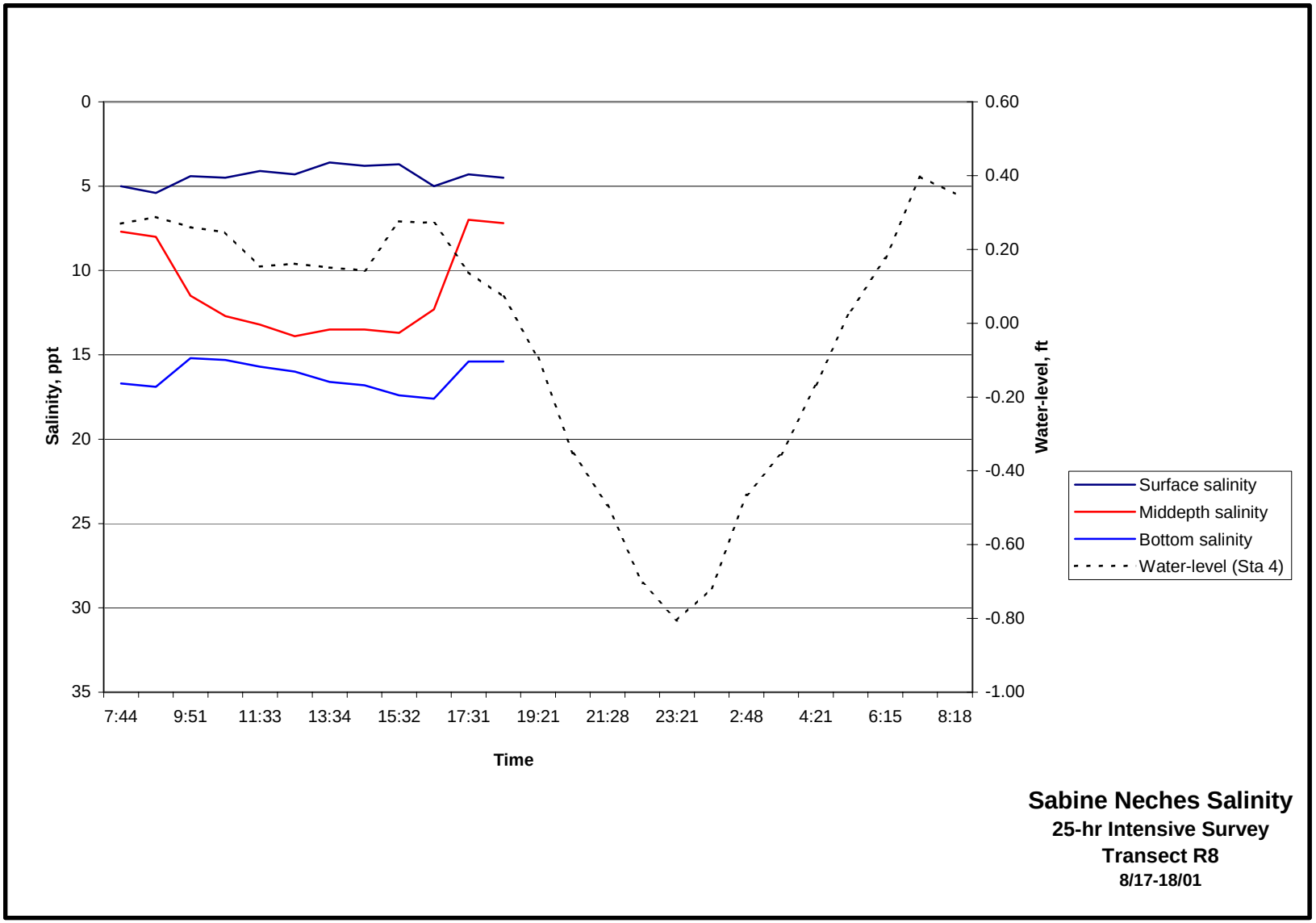

Figure 59. Salinity concentrations from water samples collected at transect R8 during 25-hr survey.

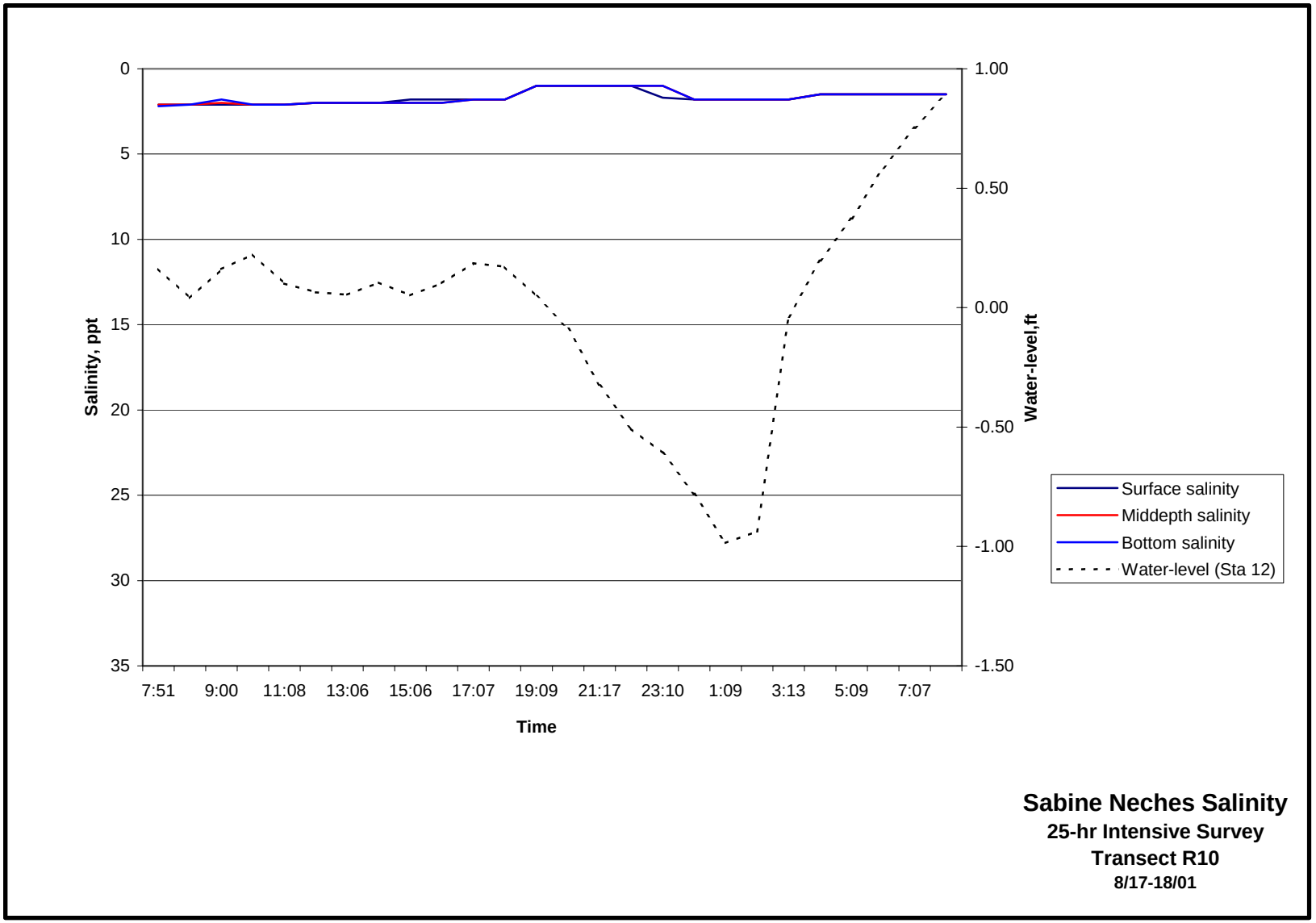

Figure 60. Salinity concentrations from water samples collected at transect R10 during 25-hr survey.

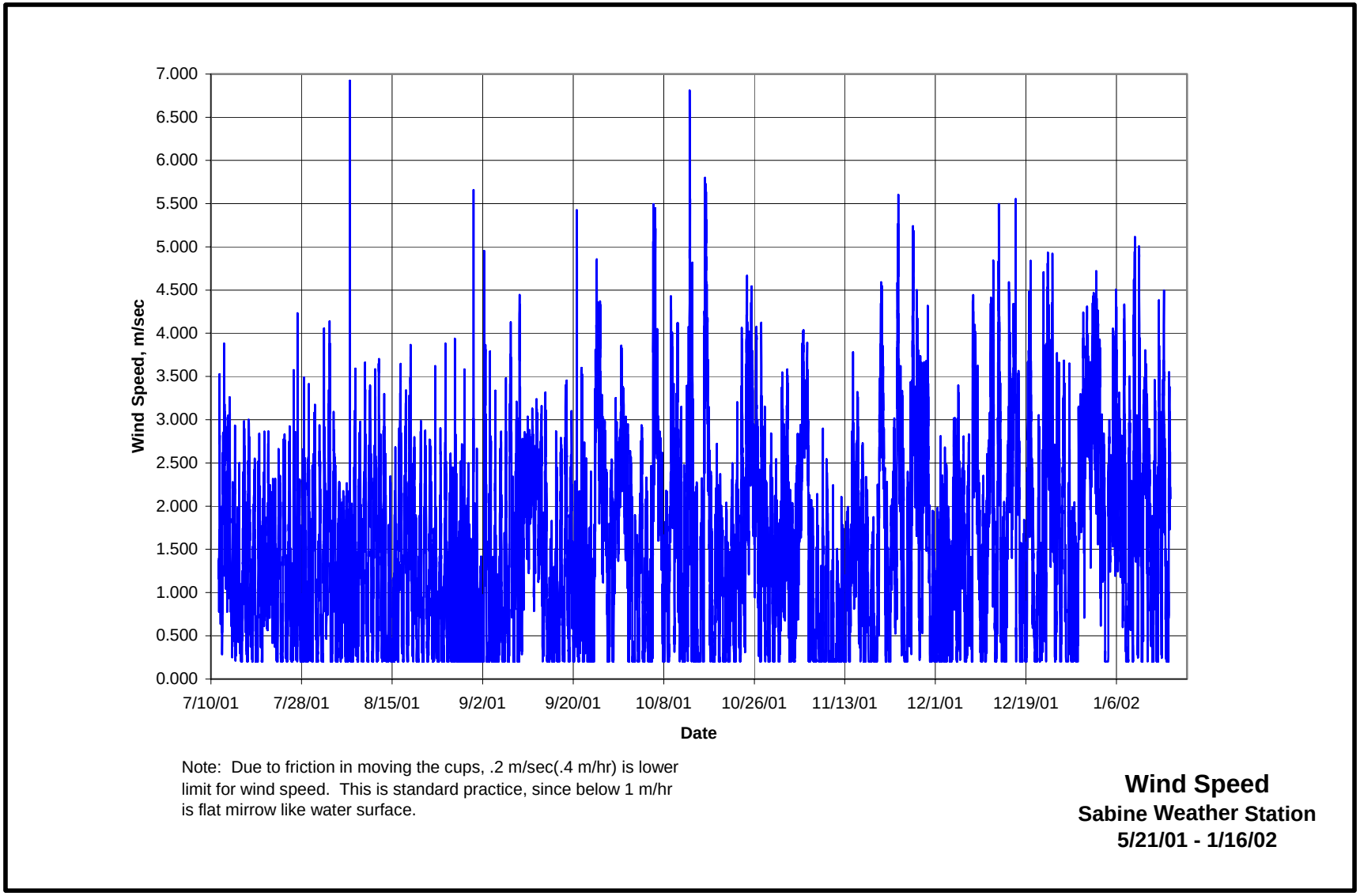

Figure 61. Wind speed record near Beaumont, Texas from 5/21/01 – 1/16/02.

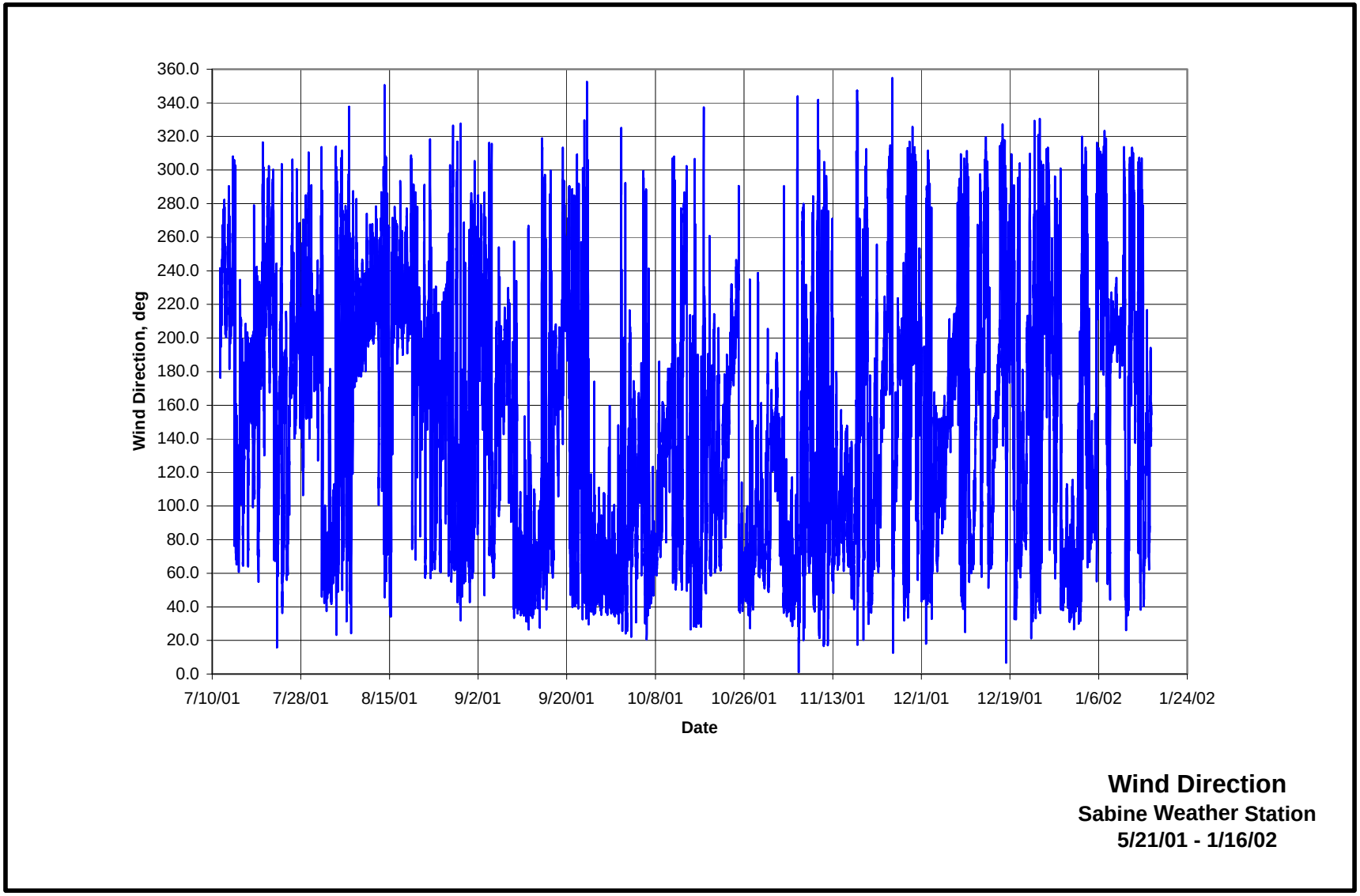

Figure 62. Wind direction record near Beaumont, Texas from 5/21/01 – 1/16/02.

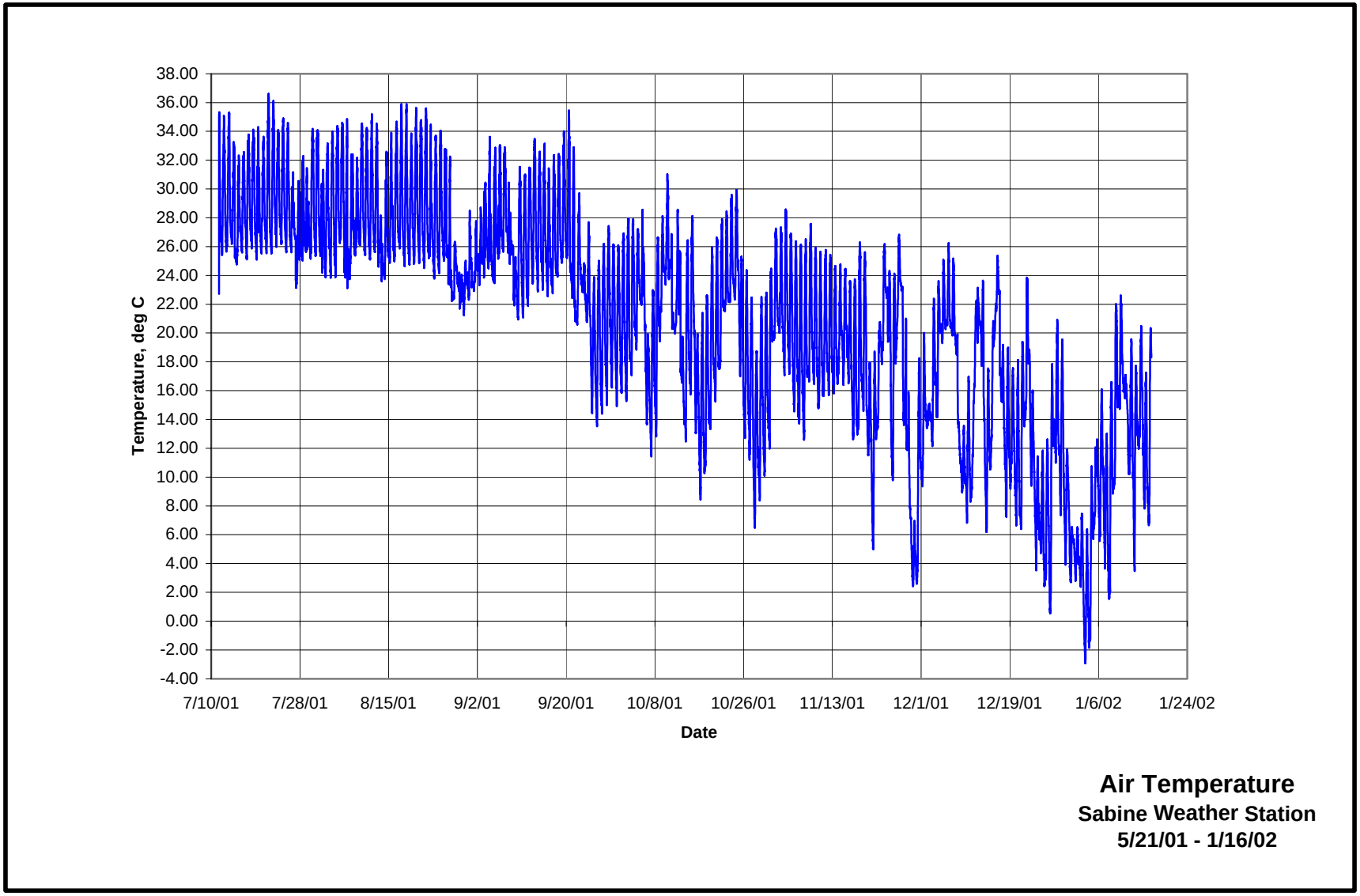

Figure 63. Air temperature record near Beaumont, Texas from 5/21/01 – 1/16/02.

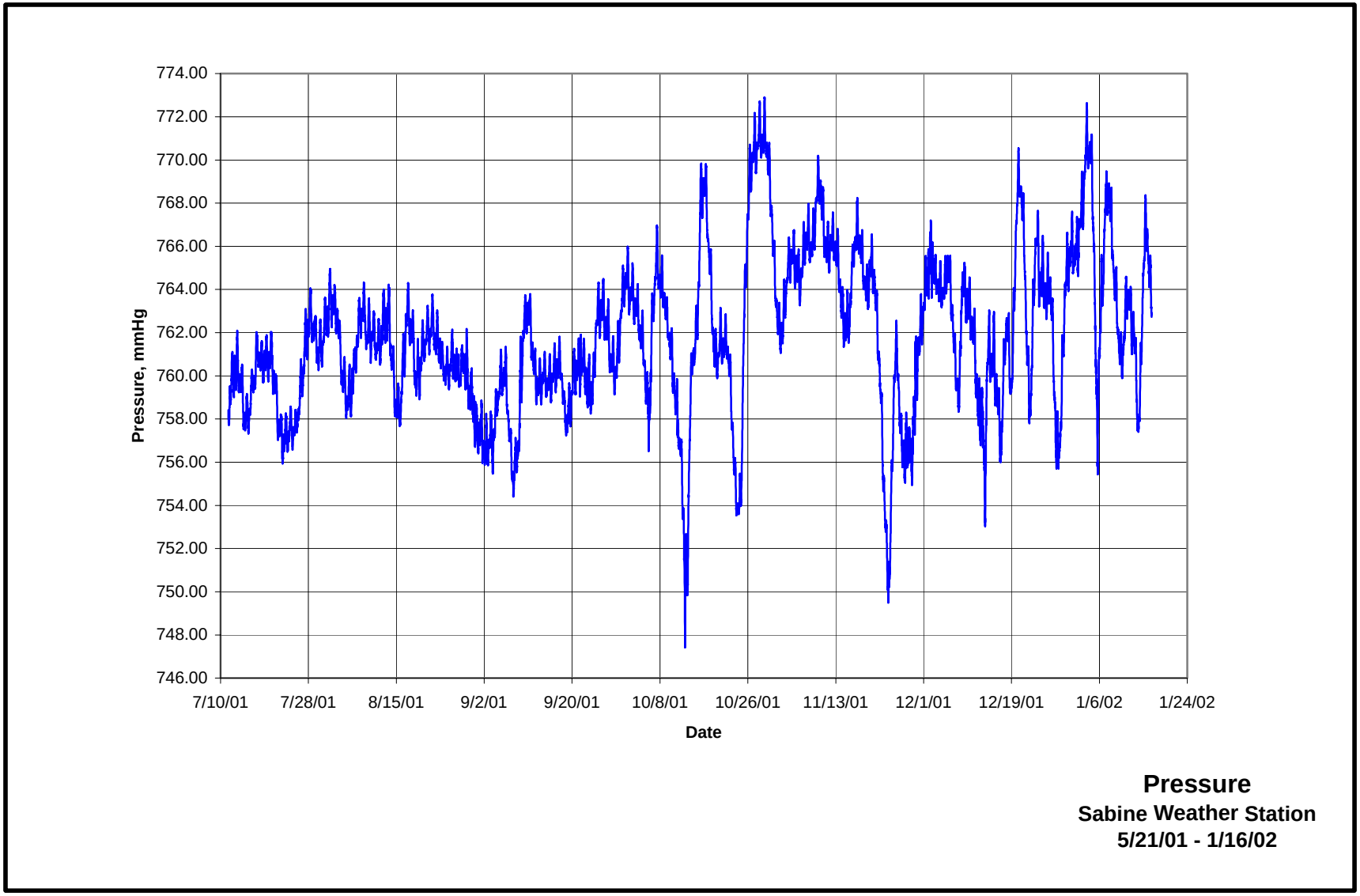

Figure 64. Barometric pressure record near Beaumont, Texas from 5/21/01 – 1/16/02.

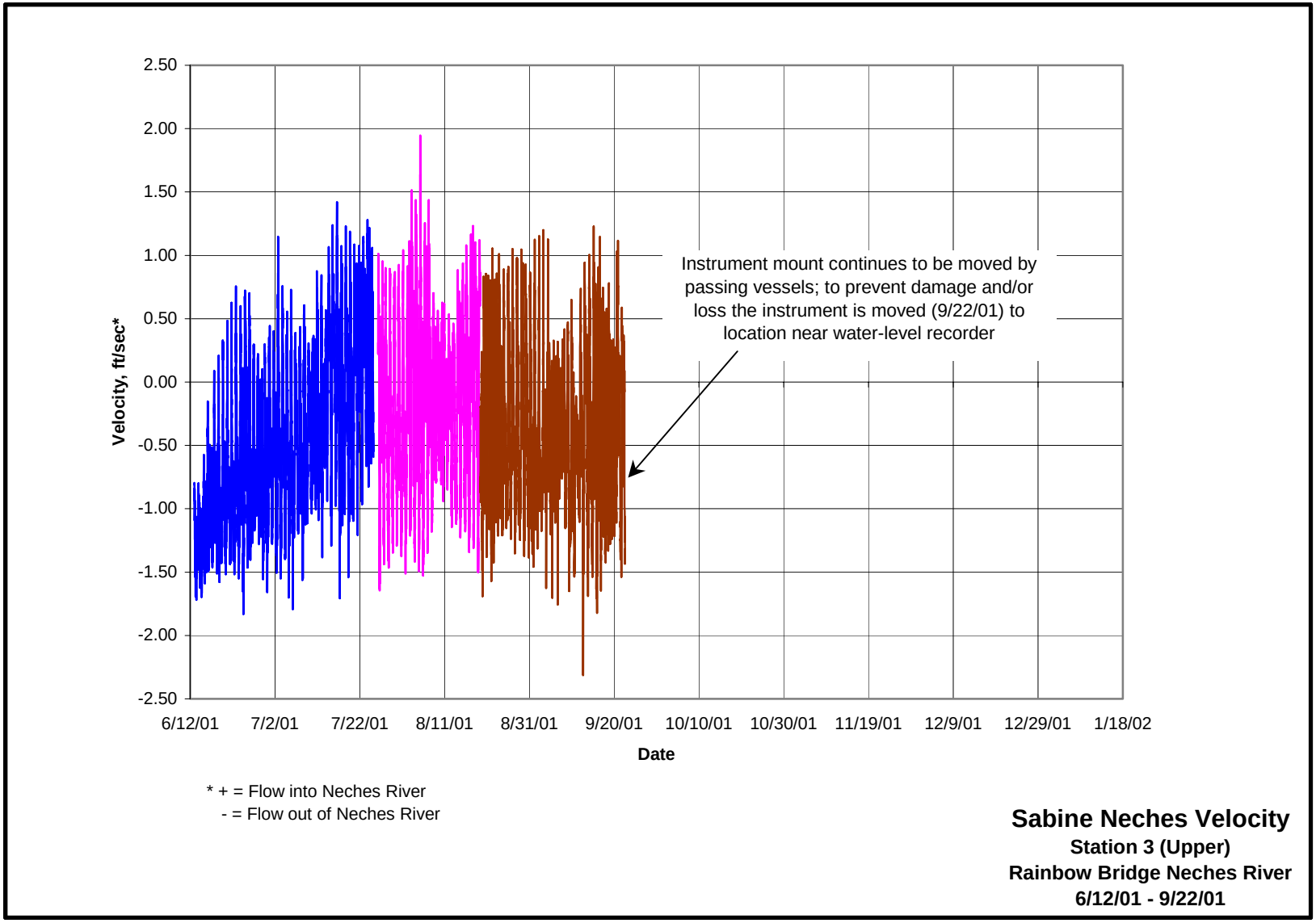

Figure 65. Velocity data records for Station 3 (upper) from 6/12/01 – 9/22/01.

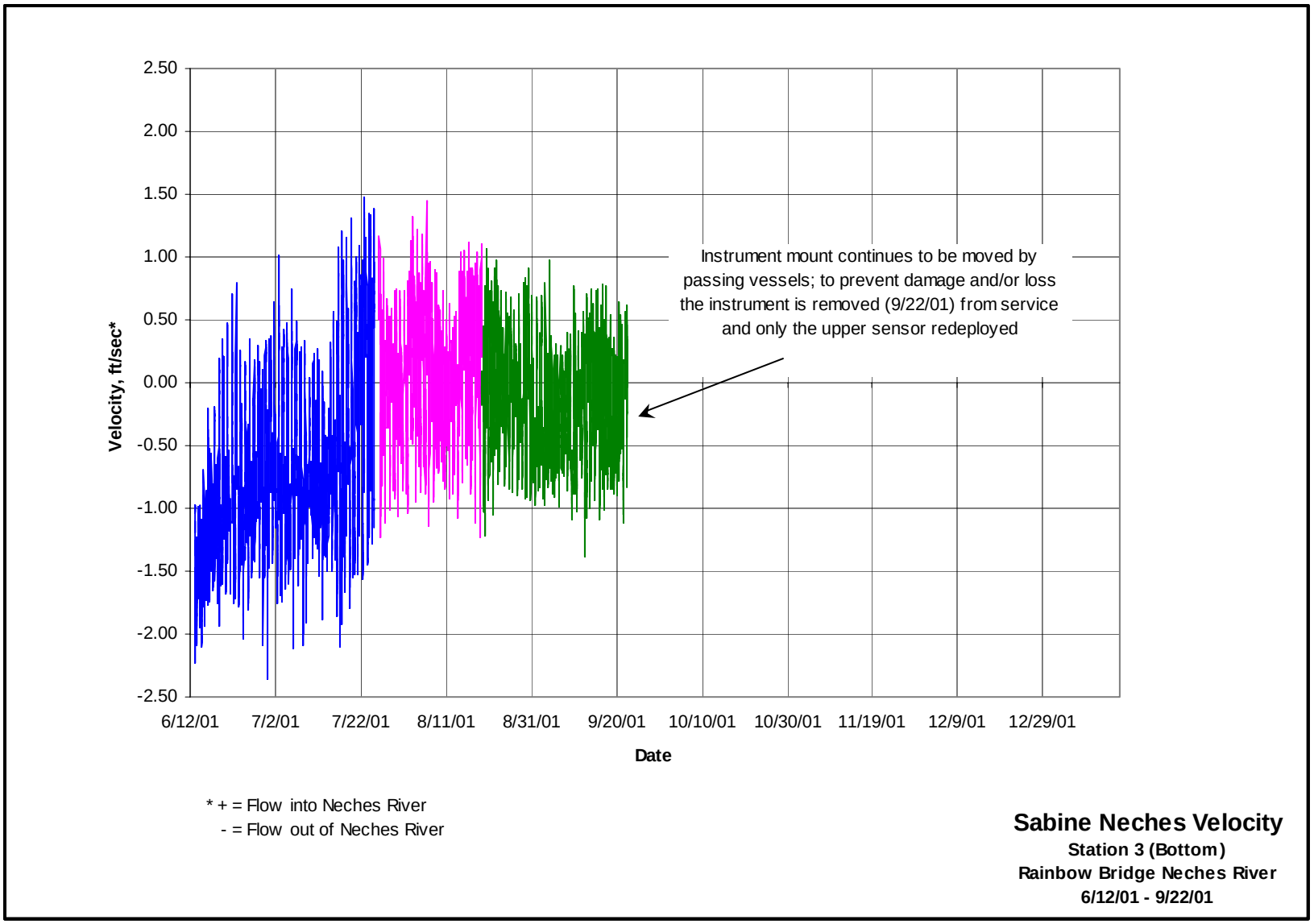

Figure 66. Velocity data records for Station 3 (bottom) from 6/12/01 – 9/22/01.

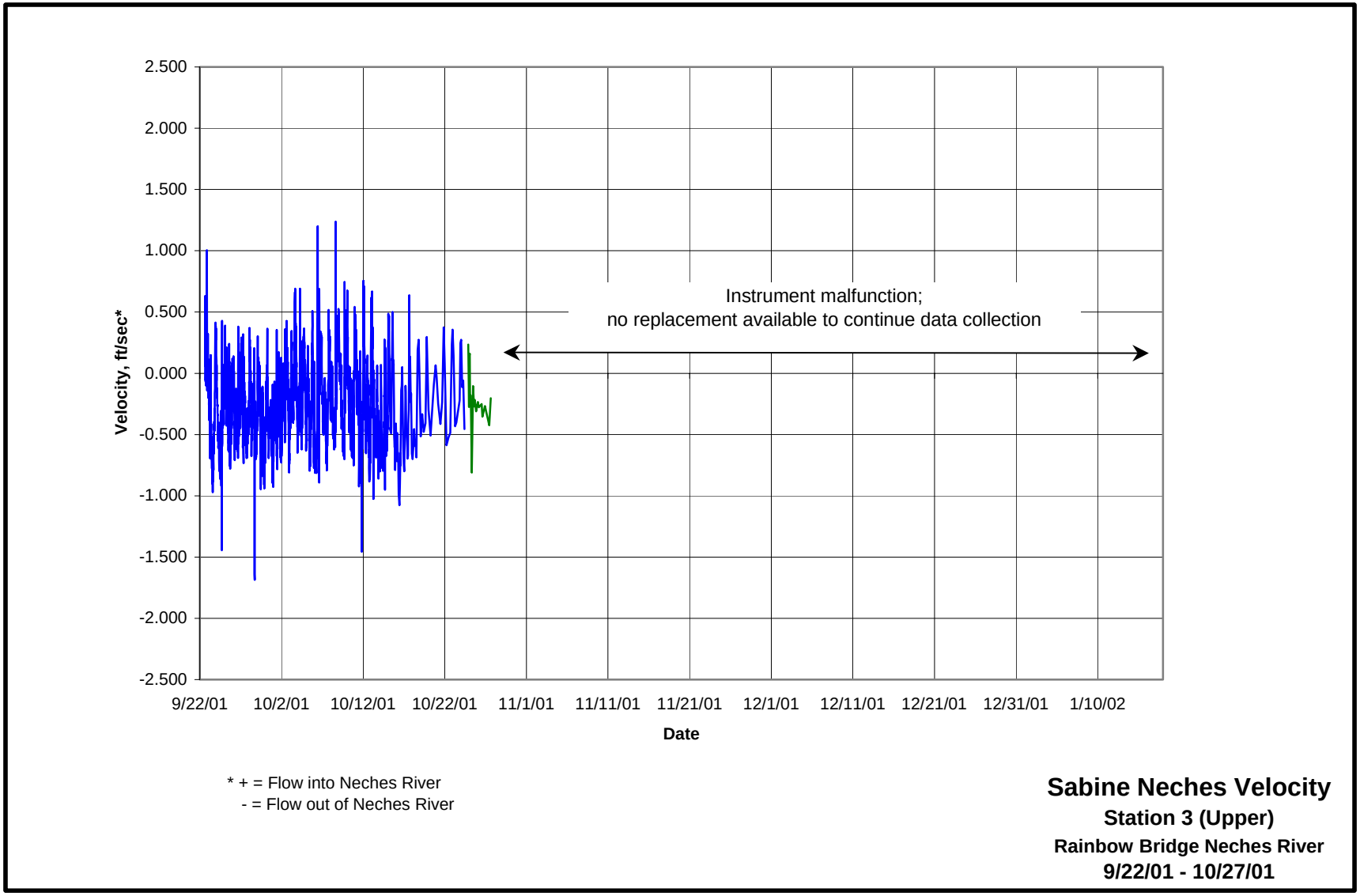

Figure 67. Velocity data records for Station 3 (upper) from 9/22/01 – 10/27/01.

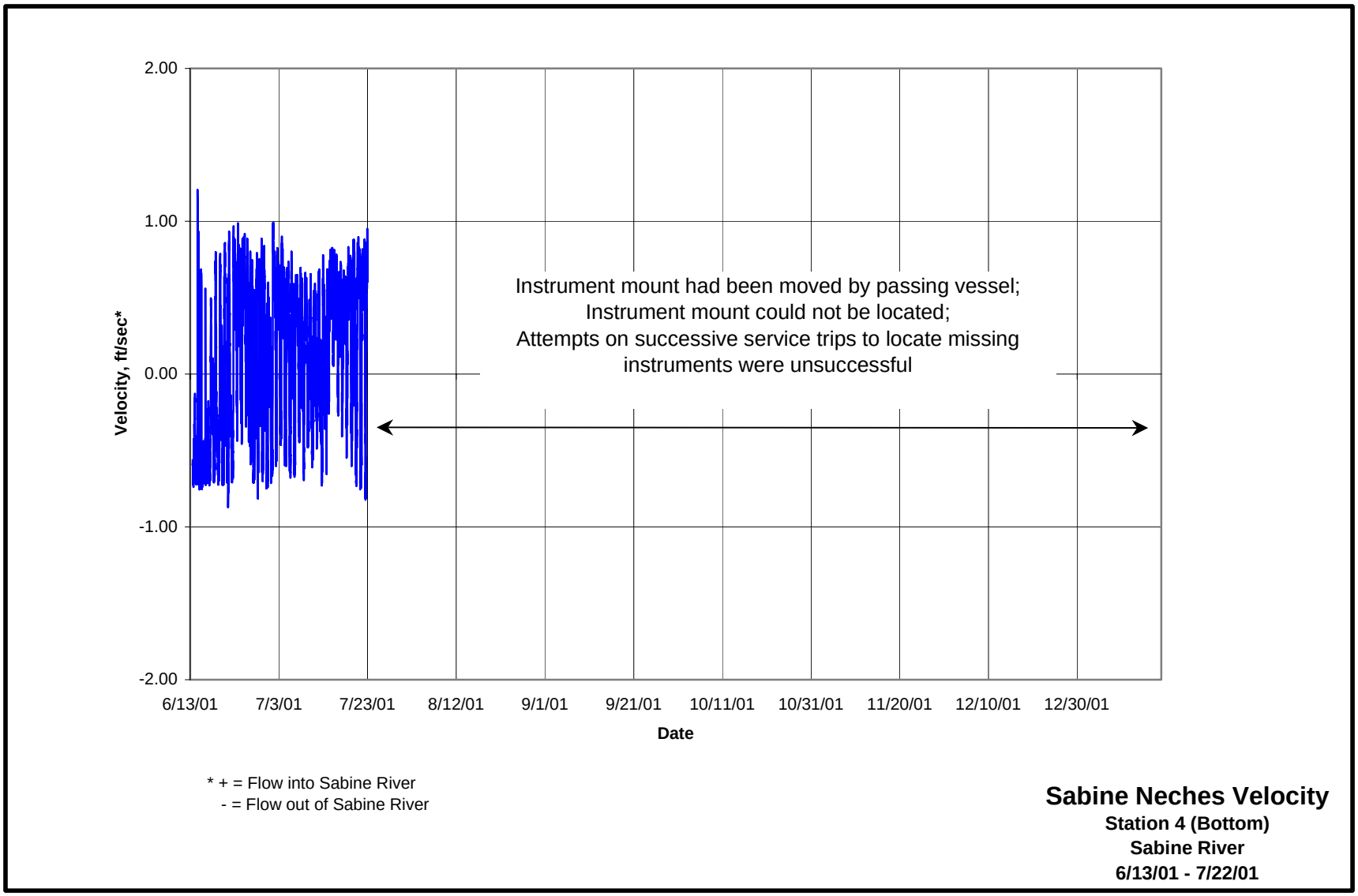

Figure 68. Velocity data records for Station 4 (bottom) from 6/13/01 – 7/22/01

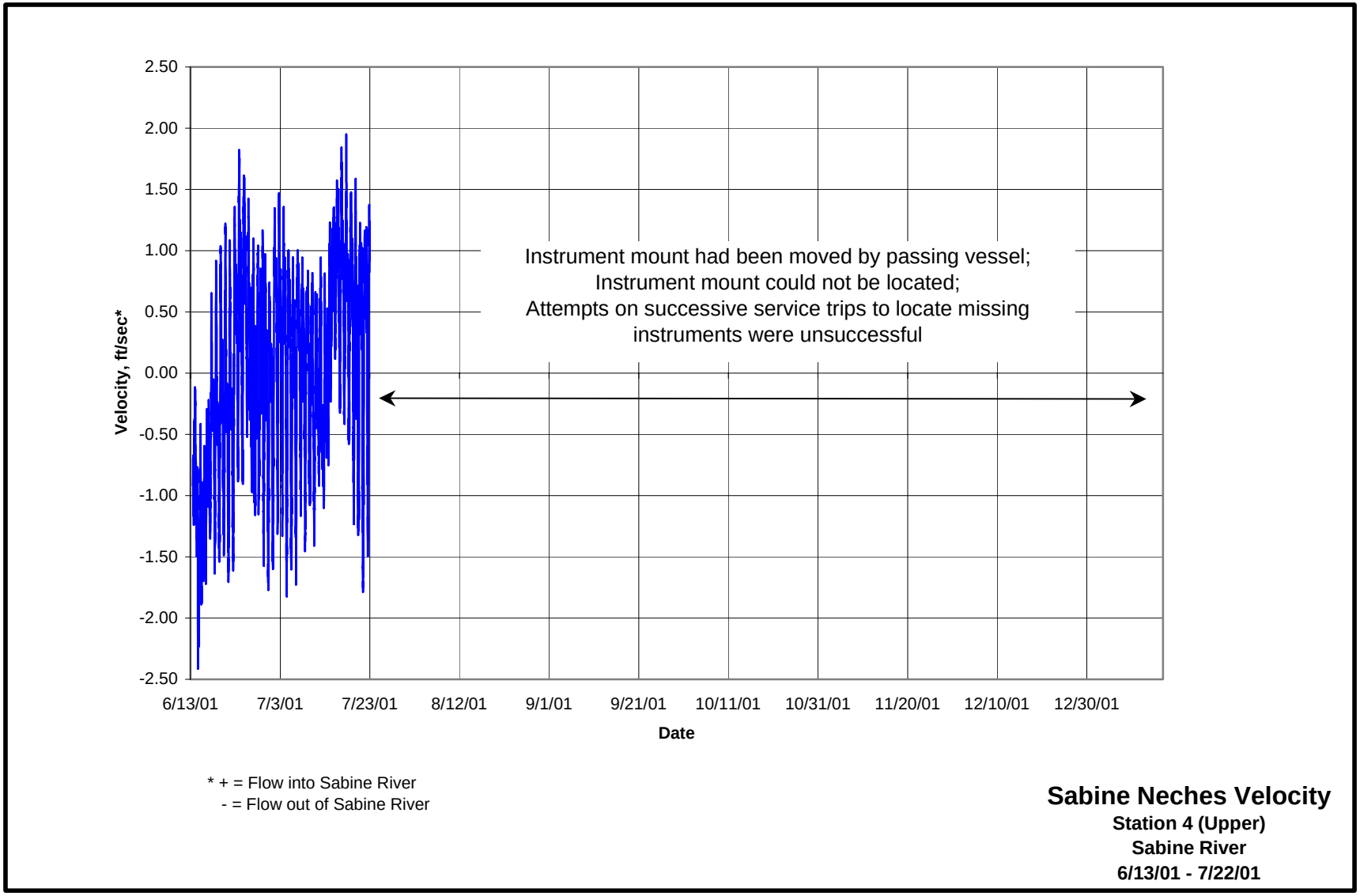

Figure 69. Velocity data records for Station 4 (bottom) from 6/13/01 – 7/22/01.

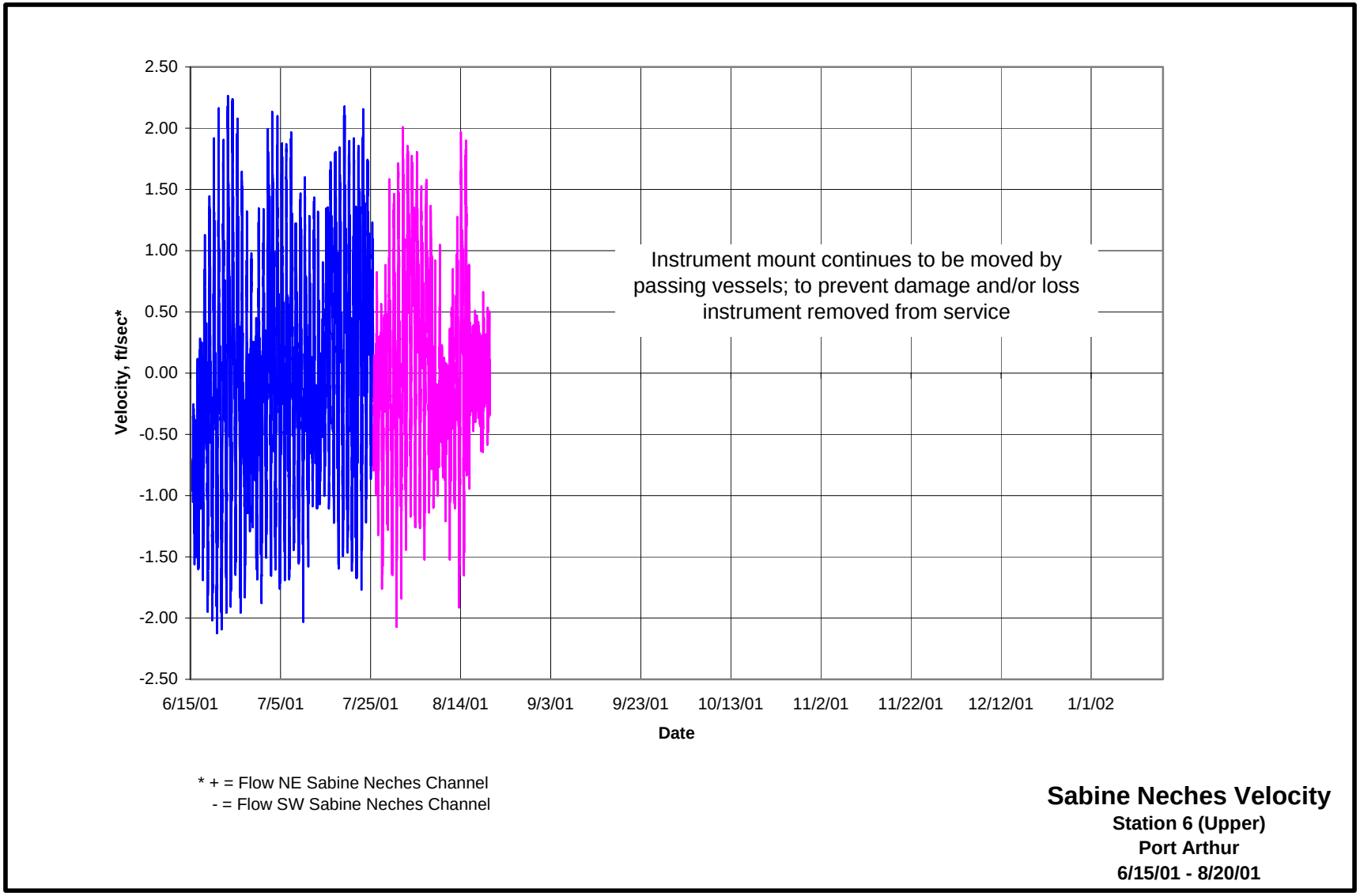

Figure 70. Velocity data records for Station 6 (upper) from 6/15/01 – 8/20/01.

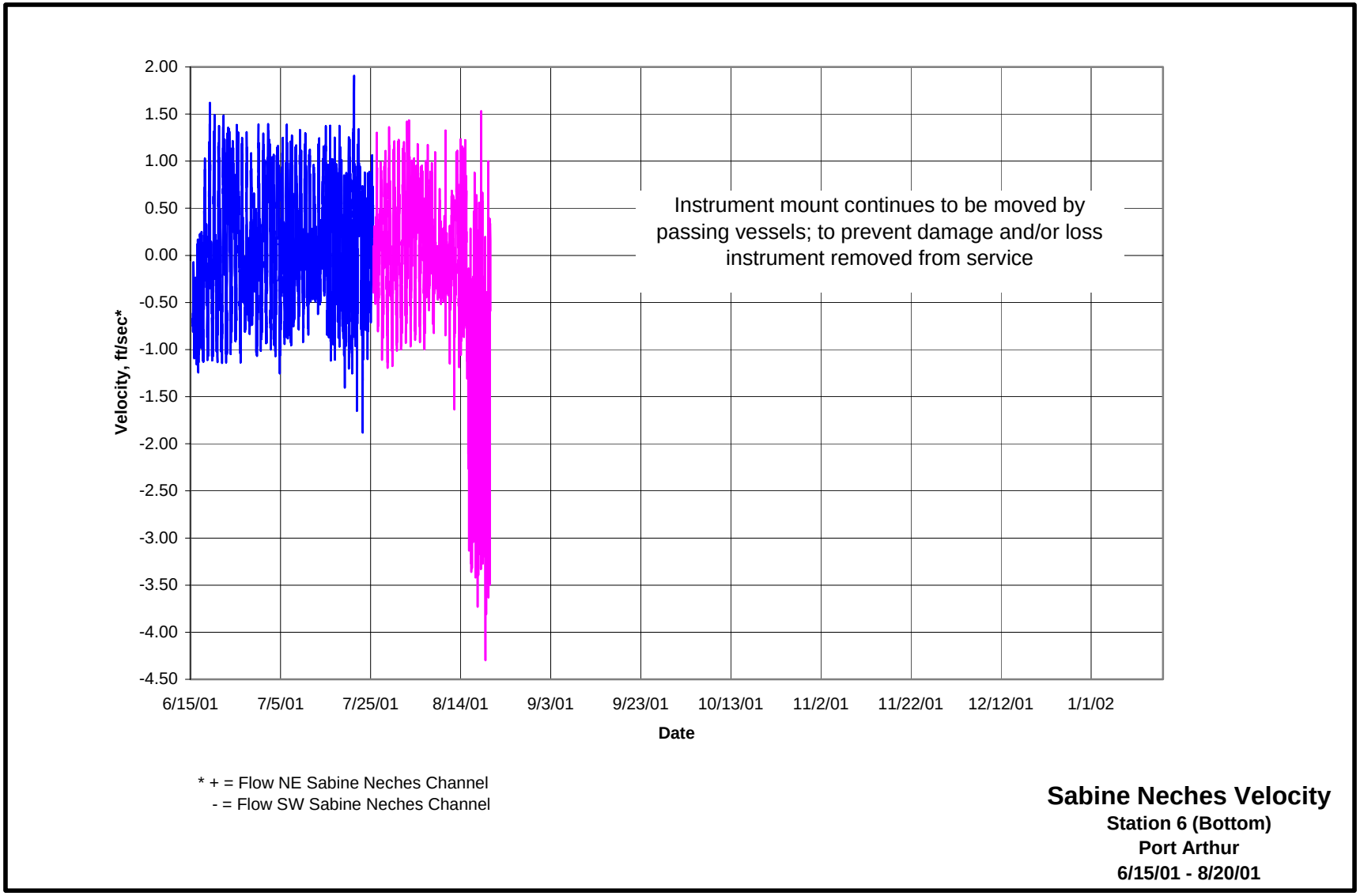

Figure 71. Velocity data records for Station 6 (bottom) from 6/15/01 – 8/20/01.

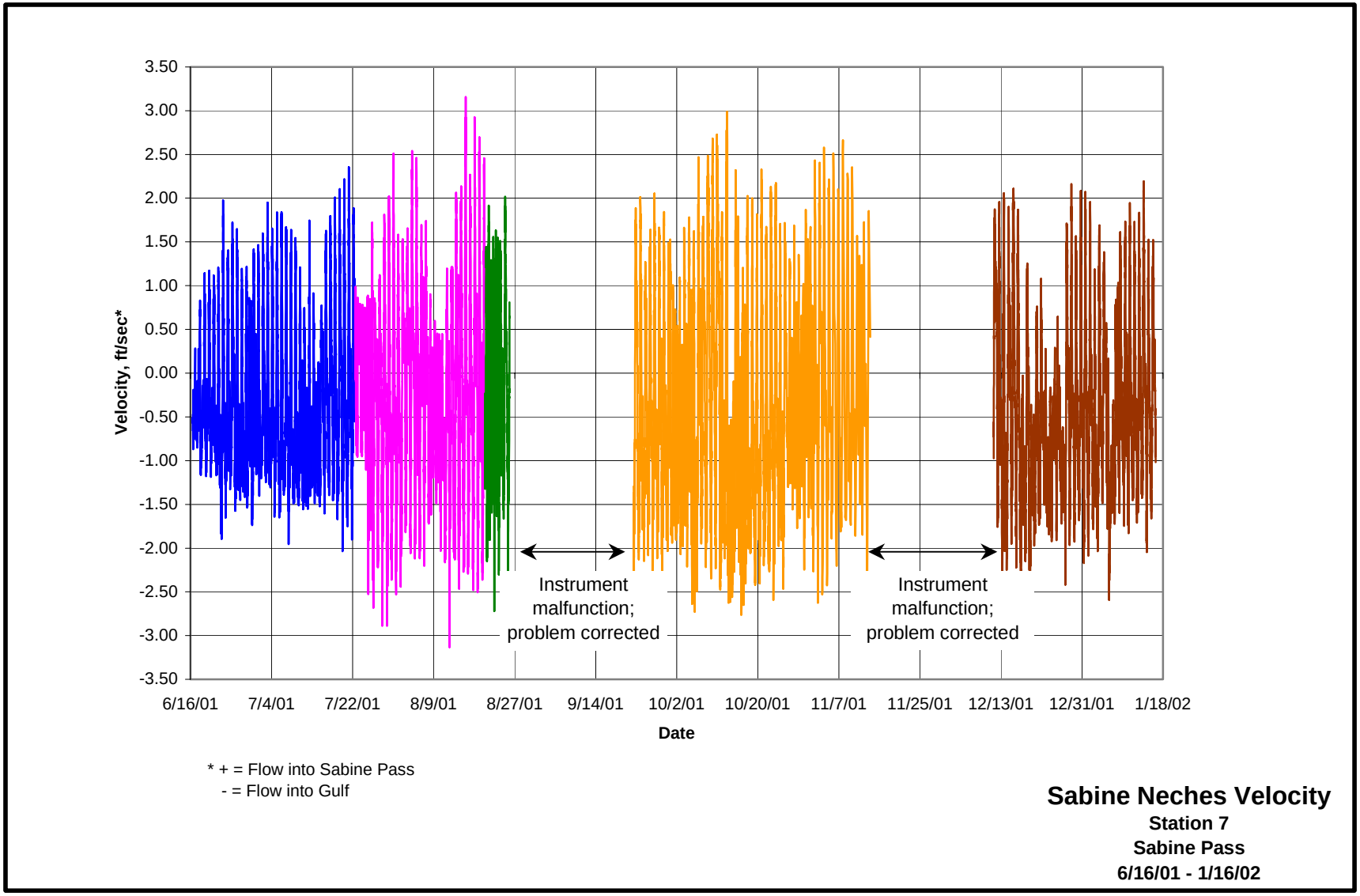

Figure 72. Velocity data records for Station 7 from 6/16/01 – 1/16/02.

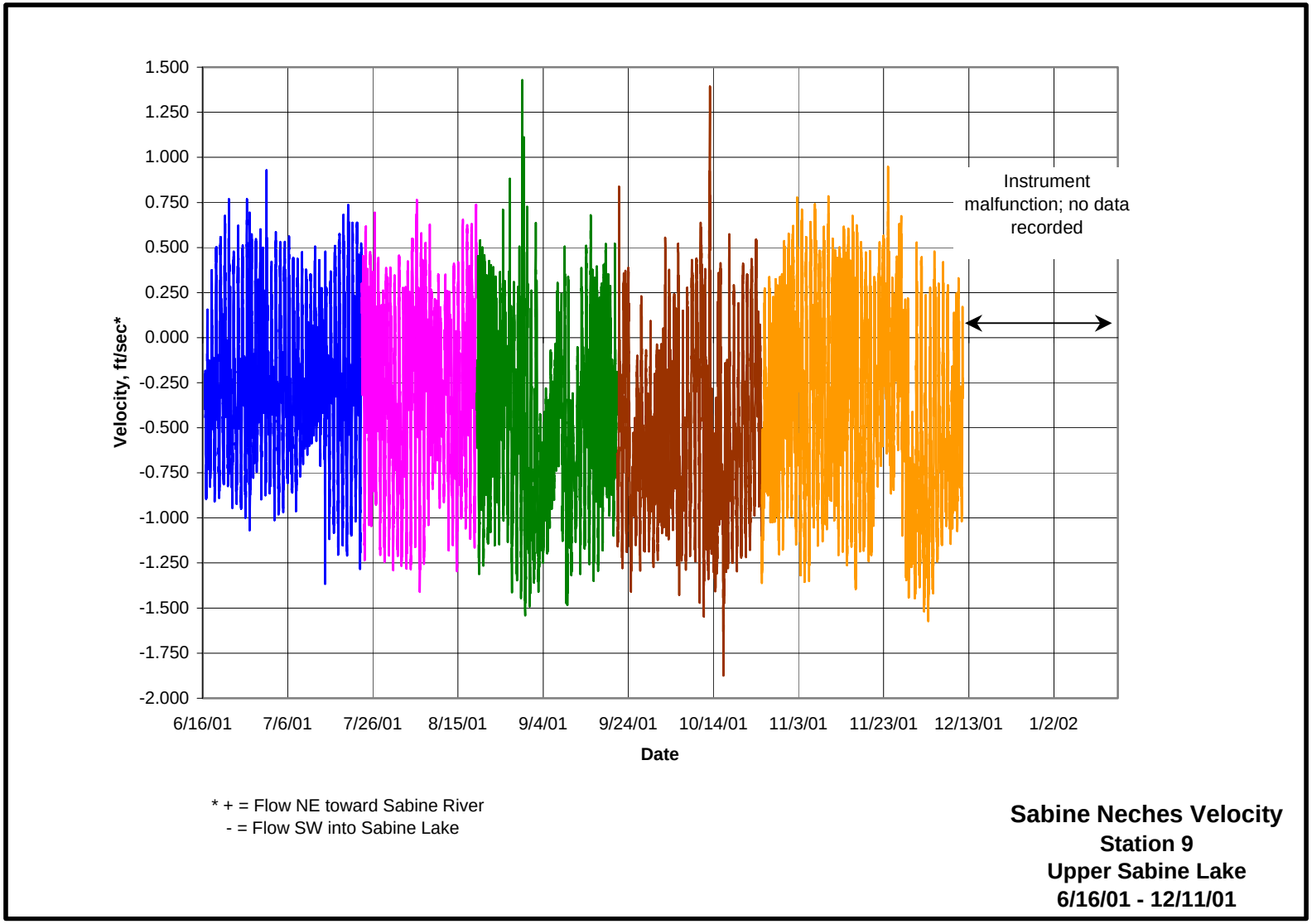

Figure 73. Velocity data records for Station 9 from 6/16/01 – 12/11/01.

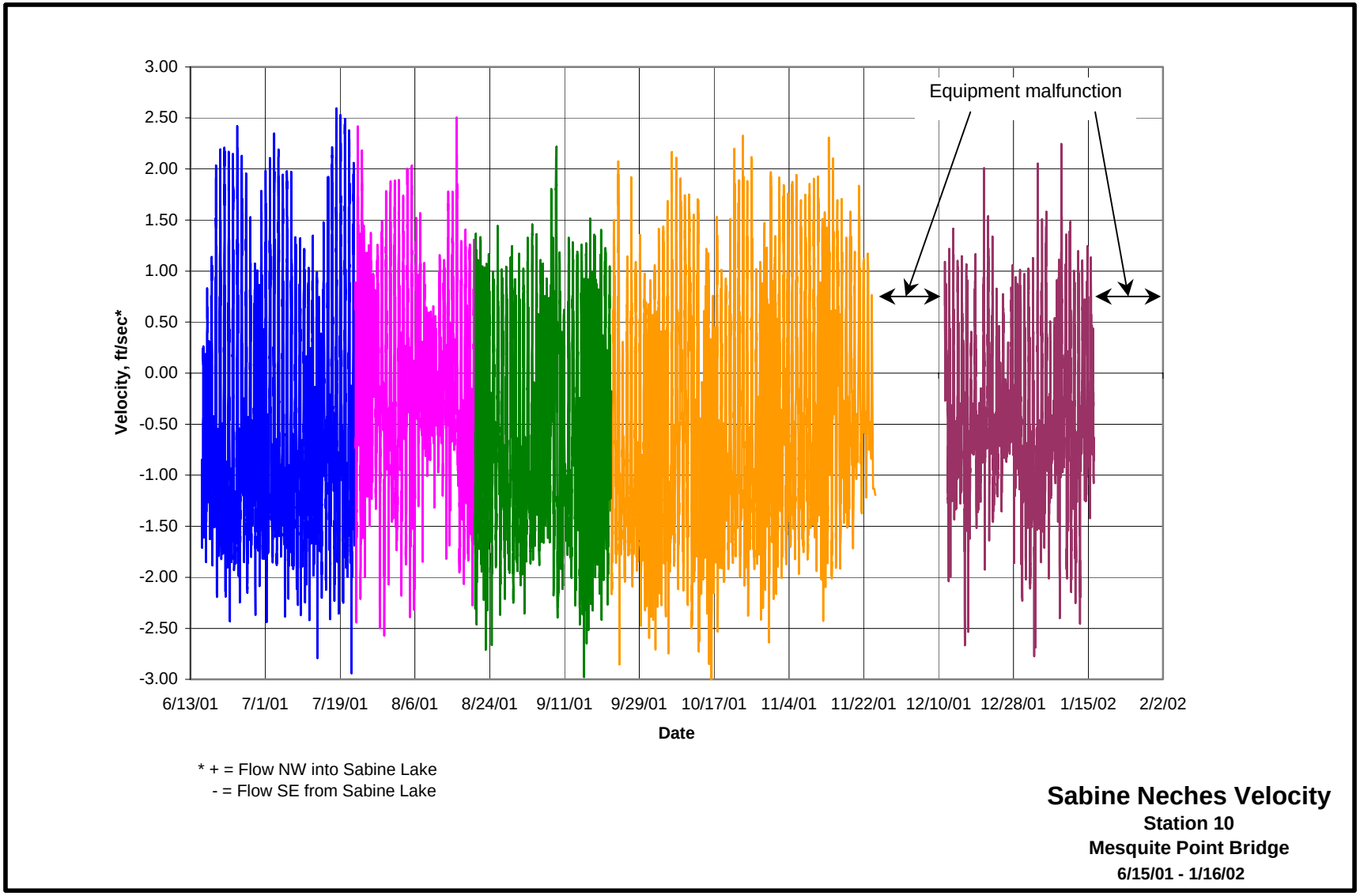

Figure 74. Velocity data records for Station 10 from 6/15/01 – 1/16/02.

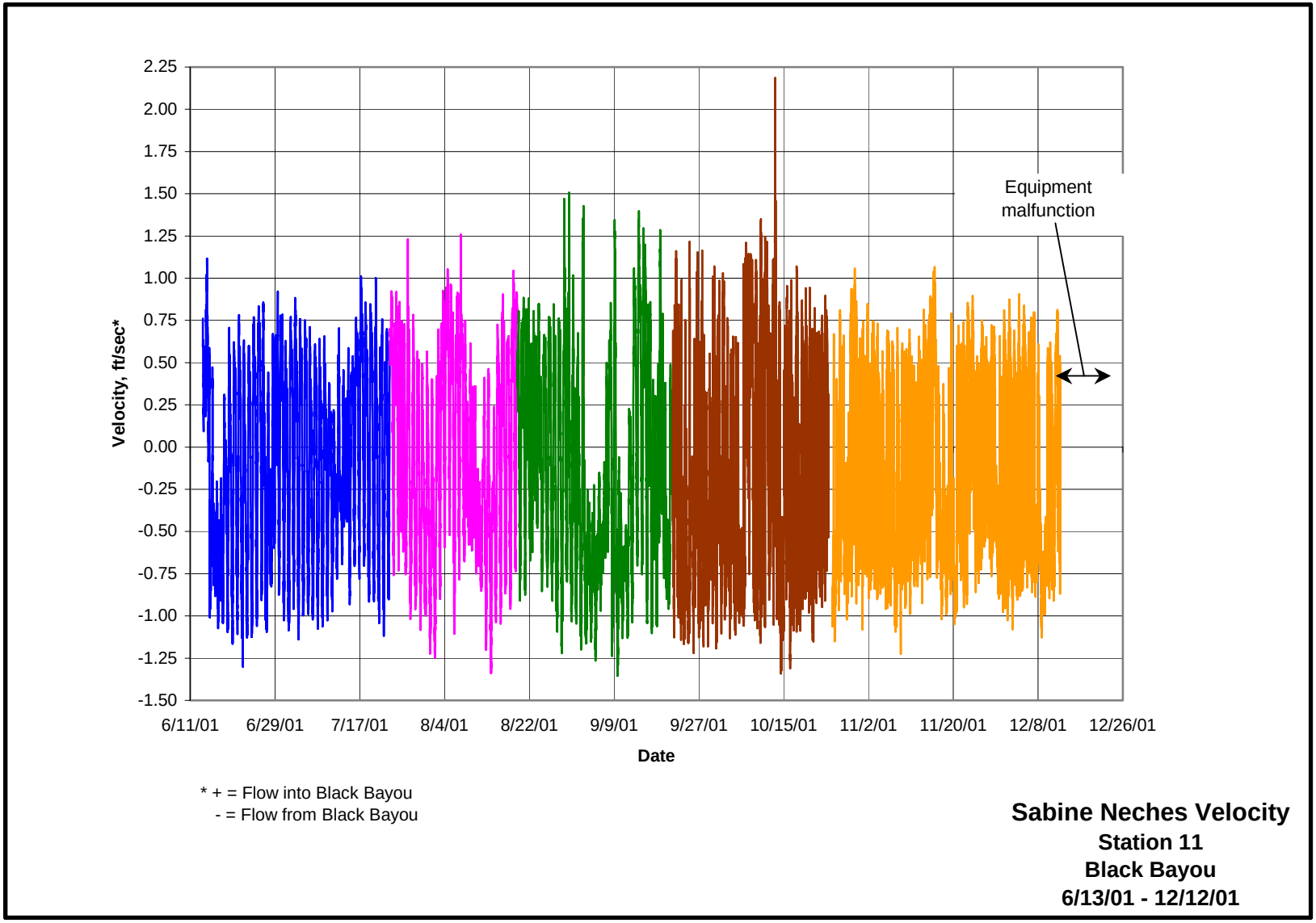

Figure 75. Velocity data records for Station 11 from 6/13/01 – 12/12/01.

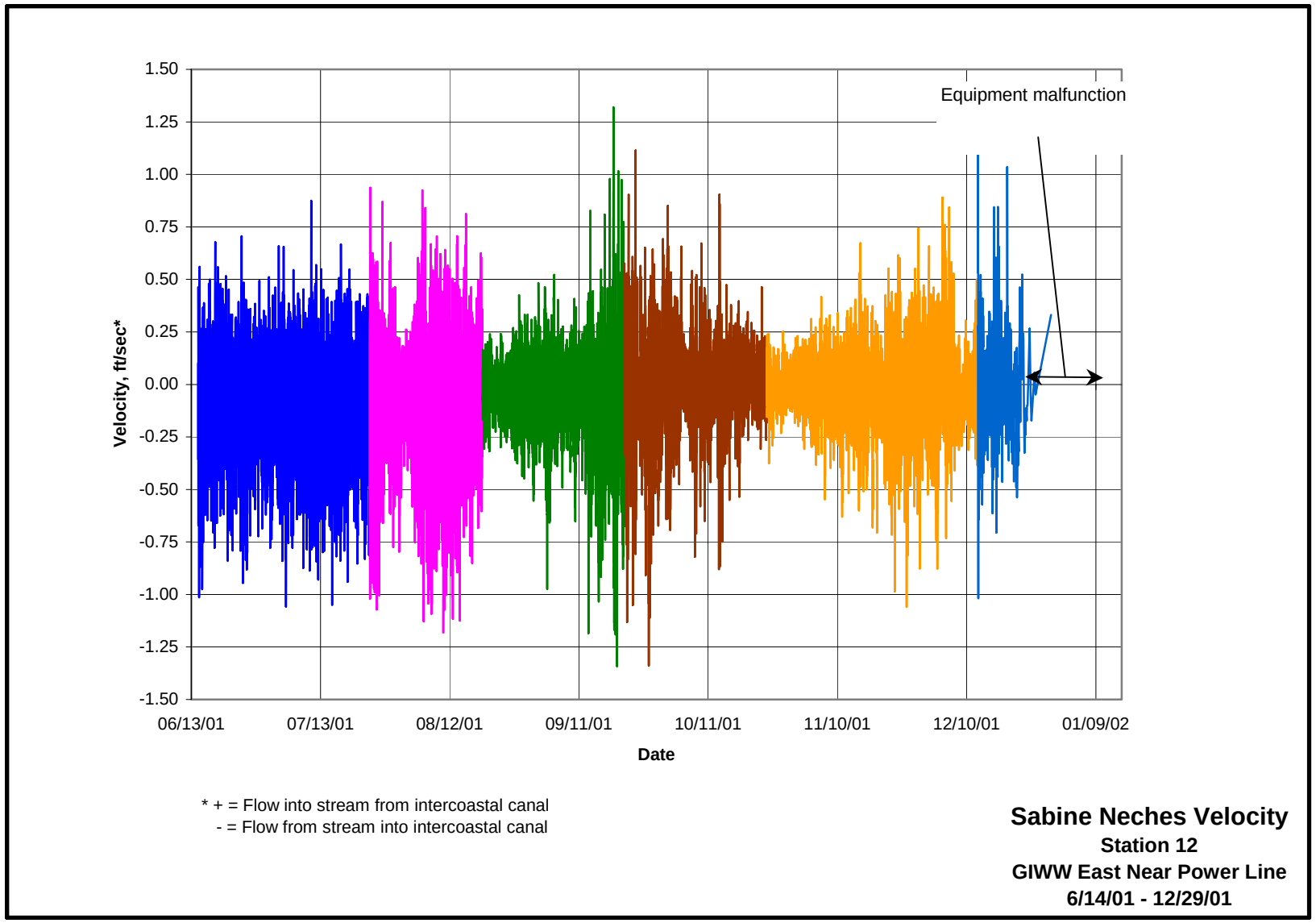

Figure 76. Velocity data records for Station 12 from 6/14/01 – 12/29/01.

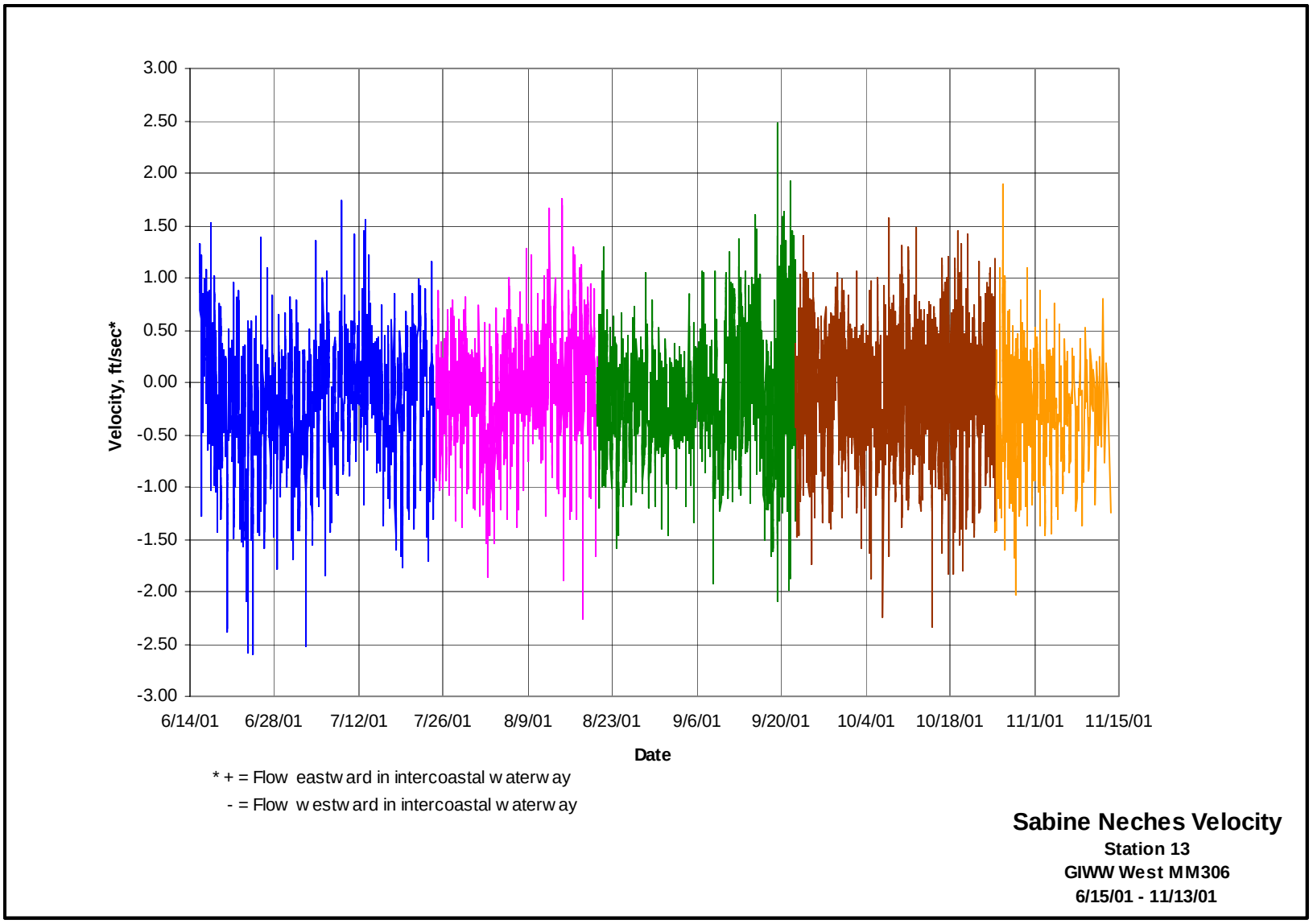

Figure 77. Velocity data records for Station 13 from 6/15/01 – 11/13/01.

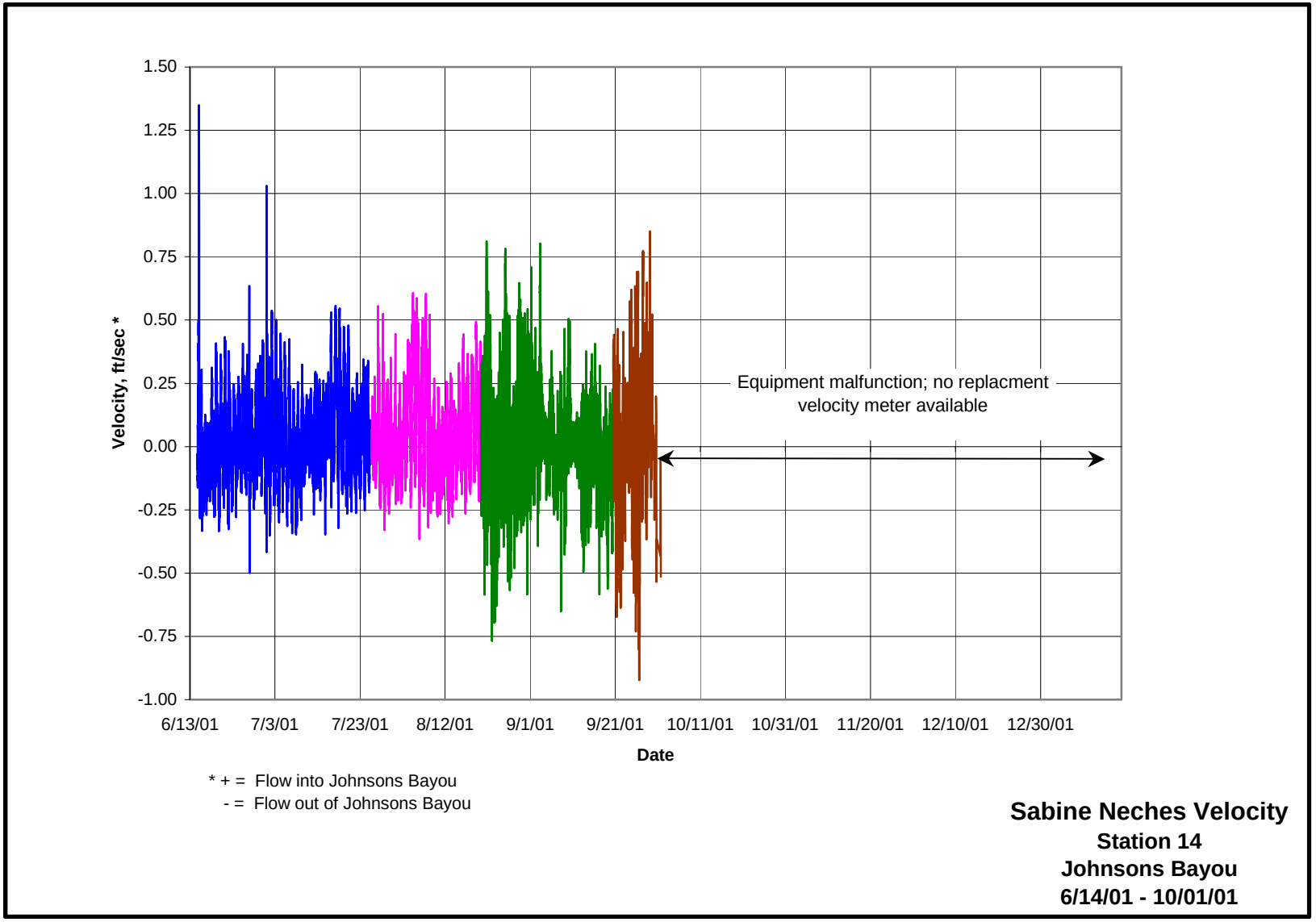

Figure 78. Velocity data records for Station 14 from 6/14/01 – 10/01/001.